OLDMAN RIVER DAM WILDLIFE HABITAT MITIGATION – VEGETATION ESTABLISHMENT –

Interim Progress Report
1989-90

Summary

Success of many of the projects of the Wildlife Habitat Mitigation Program at the Oldman River Dam in southwestern Alberta depends on establishing and maintaining vegetation at numerous sites throughout the extensive land base. Beginning in June 1989, various mitigation projects already in place at the Oldman River Dam site were surveyed and audited. Experimental programs were set up, in cooperation with the Plant Sciences Division (Vegetation Branch) of the Alberta Environmental Centre (AEC) in Vegreville, to:

- evaluate and where necessary improve the effectiveness of existing methods of protecting and enhancing plant communities,
- evaluate methods and species selection in creation of new wildlife habitat, and
- provide input into planning for supplemental and replacement plantings.

This Interim Progress Report (1989-1990) presents initial results of audits, surveys, and experiments concerning the Vegetation Establishment component of the Oldman River Dam Wildlife Habitat Mitigation Program. This report also includes short introductions to surveys and experiments planned for 1990 and 1991, and a summary of seed production being undertaken at AEC.

Results of an audit of survival at a nursery and shelterbelt planting northeast of the Dam site indicated that whereas measured survival was relatively good, the conifers were in poor shape and continued survival was doubtful. Caraganas had heavy insect damage especially in native rangeland areas. Northwest poplar were most vigourous in areas of native grassland. Some deer damage to the poplar was observed.

At a site northeast of the Dam where snow fences had been placed along the top edge of a coulee, survey plots were set up to determine if snow fences encourage invasion of shrubs from coulee slopes into grasslands. In the first year five transects each with four plots were placed and species composition and relative abundance of vascular plant species were recorded. Data will be compared over several years.

An experiment to determine the effect of snow fence on soil moisture was set up where an intermittent snow fence had been erected the previous year. Soil moisture data, collected in June and September, from several depths and distances were compared. Analysis of data indicated that whereas season was the largest, single factor affecting soil moisture and soils were drier later in the season, snow fences significantly increased soil moisture. The depth at which

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Results of an audit of survival at a nursery and shelterbelt planting northeast of the Dam site indicated that while measured survival was relatively good, the seedlings were in poor shape and continued survival was doubtful. Caragana had heavy insect damage especially in native rangeland areas. Rodents were perhaps most significant in areas of native grassland. Some deer damage to the poplar was observed.

At a site southeast of the Dam where snow fences had been placed along the top edge of a coulee, survey plots were set up to determine if snow fences encourage expansion of shrubs from coulee slopes into grasslands. In the first year five transects each with four plots were placed and species composition and relative abundance of vascular plant species were recorded. Data will be compared over several years.

An experiment to determine the effect of snow fence on soil moisture was set up where an intermittent snow fence had been erected the previous year. Soil moisture data, collected in June and September, from several depths and distances were compared. Analysis of data indicated that between depths, was the most significant factor affecting soil moisture and soils were drier later in the season; snow fences significantly increased soil moisture. The effect of which

samples were taken and the distance from the fence line also significantly affected soil moisture readings. Generally soils were drier at greater depths, although surface samples were drier than those taken just below the surface. Soils farther from the fenceline contained more moisture as would be expected since the land sloped away from the fence on the leeward side. The greatest increases in moisture behind the snow fence were at 2 m, 4 m, and 8 m from the fenceline. At 16 m there was no increase in soil moisture in snow fenced areas. A smaller increase was observed at both 1 m and 32 m from the fenceline. The interaction between season and the presence or absence of snow fences was also significant. Although there was a greater net loss of soil moisture from samples taken behind snow fences, soil moisture remained higher in samples taken from snow fenced areas at both sampling times (June and September).

Permanent survey plots were placed in a heavily grazed, *Agropyron/Stipa* community which had been fenced and protected from further grazing in spring of 1989. Six plots were placed and relative abundance of each vascular plant species was documented. Plots will be monitored annually to determine changes in species composition. Information will be available for calculating increases in wildlife habitat, and for planning controlled grazing at similar sites within the land base around the Oldman River Dam Reservoir.

An experiment was set up in a grassland area north of the future reservoir to determine effects of snow fences on the recovery of a heavily grazed *Agropyron/Koeleria/Stipa* community when grazing ceases. An 3-factor, split, split plot design with four replicates was set up in the field in 1989. Above-ground biomass was measured and species composition and relative abundance were documented. Analysis of data determined that there was no significant difference in above-ground biomass among plots which will receive different treatments. Snow fencing was placed in the fall of 1989, and assessments of above-ground biomass will be carried out annually. Data will be analysed to determine differences between snow fenced and unfenced areas, taking into account distance and direction from the fenceline.

New projects were proposed for 1990 and 1991. These include auditing survival of trees and shrubs planted in 1989, and new projects and experiments to obtain specific information regarding vegetation establishment at the Oldman River Dam Site. Specific experiments include:

- fertilizer trials with Douglas fir seedlings,
- an experiment to determine effects of snow fences on tree and shrub establishment,
- field trials of grass and forb seed mixtures to be used in reclamation plantings on site at the Oldman River Dam, and

- a study of effects of grazing on biomass production which will assist in the preparation of a long-term grazing management plan.

The final section of this progress report outlines seed production work being carried out at AEC. Existing stocks of forb seeds were tested for germination and 27 species were sown indoors and transplanted to a field plot in the summer and fall of 1989. These plants will produce seeds in 1990 and 1991. Seeds will be available for use in wildlife habitat mitigation projects at the Oldman River Dam or for large scale seed multiplication programs. Native forb and grass seeds were collected on-site at the Oldman River Dam in 1989. These were tested for germination in winter (1989-1990) and will be sown in the spring (1990) for further seed production. A selection program for forbs is strongly recommended and could be established at AEC to complement a similar program for native grasses.

Further investigations in 1990 and 1991 will provide much needed information regarding numerous aspects of vegetation establishment at the Oldman River Dam site, and allow managers and planners to make informed decisions regarding land use both now and in the future.

Contents

List of Tables

List of Figures

List of Appendices

Acknowledgements

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1 INTRODUCTION

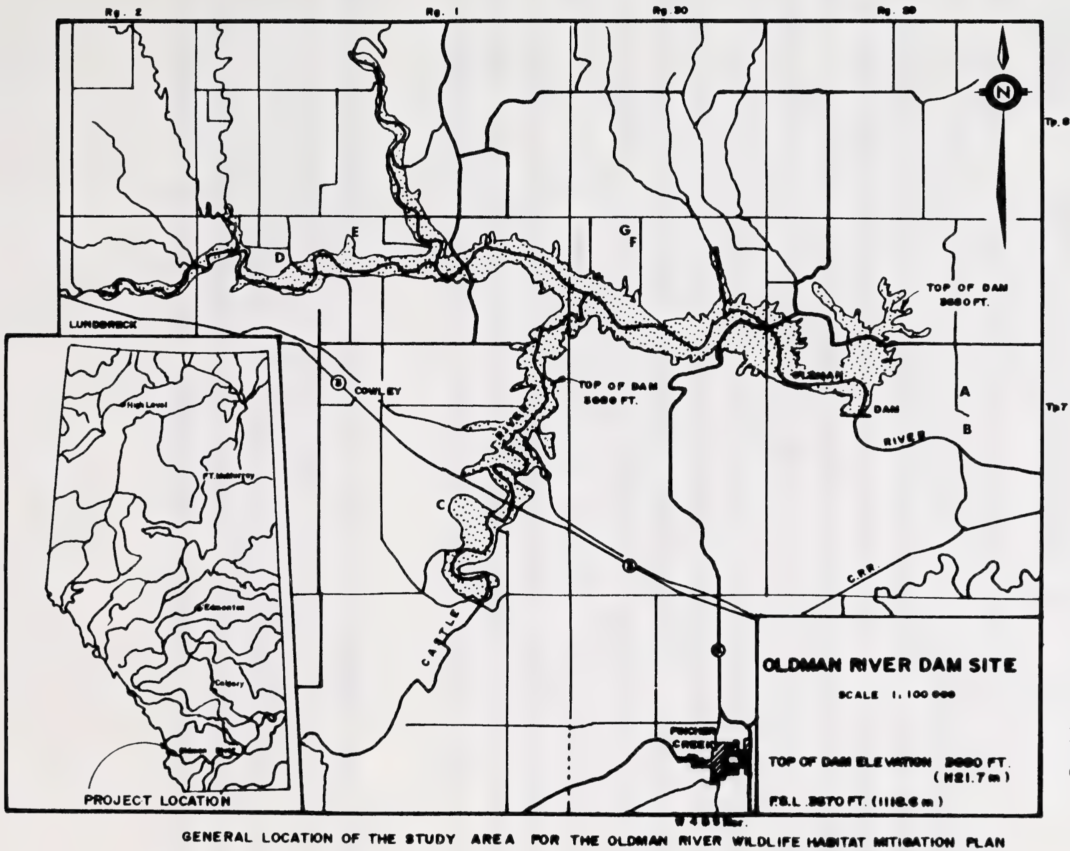
The Oldman River Dam, first announced in 1984, is being built in southwestern Alberta 10 km northeast of Pincher Creek; just east of the confluence of the Oldman, Castle, and Crowsnest Rivers (Figure 1). The primary function of the dam and the resulting reservoir will be storage of meltwater from sources in the Rocky Mountains during times of maximum flow (mid-May to mid-July) to provide a dependable water supply throughout the year for agricultural, municipal, industrial, and recreational uses in Alberta, and provide required flow to downstream provinces. Construction of the dam began in 1988 and is expected to be complete in the fall of 1990. Water storage will begin in the spring of 1991. The reservoir will cover an estimated area of 2400 ha, and will be approximately 24 km long and up to 3 km wide. Water depth will exceed 60 m in some parts.

To cope with the environmental disturbance that would inevitably arise from the construction and eventual flooding, the Planning Division of Alberta Environment initiated studies which led to Environmental Mitigation/Opportunities Plans for various aspects of concern including environment (wildlife and fisheries), historical resources, and recreation (Alberta Environment 1988a, 1988b).

Work began on the wildlife portion of the Environmental Mitigation /Opportunities Plan in 1985 and 1986 with a review of pertinent information, followed by field surveys of wildlife. A vegetation survey, conducted in 1984 and 1985, described major plant communities and discussed dominant factors controlling vegetation in areas surrounding the future reservoir site (Hardy and Associates (1978) Ltd. 1986). The publication also included a brief reclamation plan and recommendations concerning procedures and methods for preserving and restoring native vegetation.

The Delta Environmental Management Group Ltd. (the Delta Group) was retained by Alberta Environment in 1987 to prepare a strategy for wildlife habitat mitigation at the Oldman River Dam Site. Their objectives were to:

Figure 1. Location of study plots at the Oldman River Dam Site.



A. Shelterbelt and nursery plantings (2.1.1).

B. Snow fence effects on tree and shrub encroachment (2.1.2).

C. Soil moisture behind snow fences (2.1.3).

D. Grassland recovery (2.1.4).

E. Grassland restoration (2.2.1).

F. Fertilizer effects on Douglas Fir establishment (3.2.1).

G. Effects of snow fences on tree and shrub establishment (3.2.2).

> '...identify opportunities for wildlife habitat mitigation in the vicinity of the reservoir and on the basis of this inventory, develop practical and effective projects to protect, enhance, or create wildlife habitat during 1988 to 1993.' (Green and Eccles 1989).

An action plan was formulated by the Delta Group in cooperation with personnel from Alberta Public Works, Supply and Services (PWSS) (Nilson and Green 1989). Projects were presented along with an implementation schedule, and an evaluation and monitoring plan for wildlife habitat mitigation projects.

Three major mitigation techniques were recommended and are now being implemented. The first is **protection** of important wildlife habitat which already exists in the vicinity of the reservoir. This is being accomplished by acquiring both crown and private lands and reducing grazing pressure (i.e. by erecting fences to exclude cattle). The second major method is habitat **enhancement**. This includes techniques undertaken to modify or improve sites to increase their use by wildlife. Enhancement includes placement of snow fences to improve soil moisture and planting of trees and shrubs around existing wetlands and in other suitable areas. New wildlife habitats are also being **created** by construction of riparian dams and check dams and planting appropriate plant species (i.e. those which will provide erosion control and provide food and shelter for wildlife). Other projects involve creating or enhancing nesting sites for raptors, providing suitable structures for duck nesting sites and providing structures for other animals. These however, do not involve modifying vegetation and therefore will not be considered further in this report.

Since the objective of wildlife habitat mitigation is to provide wildlife with sufficient habitat to replace that being lost to flooding in 1991, the success of the program will be measured by the eventual use by wildlife and survival of wildlife after flooding. Success of many individual projects however, depends on establishment of specific plants and enhancement of vegetation. Success also depends on the potential for

natural regeneration of improved vegetation. Only the vegetation aspects of specific projects are considered in results and plans reported here.

Beginning in June of 1989, various mitigation projects at the Oldman River Dam site were surveyed and audited. Experimental programs were set up, in cooperation with the Plant Sciences Division (Vegetation Branch) of the Alberta Environmental Centre (AEC) in Vegreville, to evaluate and where necessary improve the effectiveness of existing methods of protecting and enhancing plant communities, to evaluate methods and species selection in creation of new wildlife habitat, and to provide input into planning for supplemental and replacement plantings.

This interim report consists of results of surveys of projects which were started prior to 1989, the design and preliminary results of an experiment started in 1989, and plans for future work including surveys and monitoring, and experiments designed to study specific aspects of the vegetation establishment. Also included is a description of germination and production work being carried out at AEC which is directly related to mitigation work at the Oldman River Dam Site.

The first part of this report consists of audit results for specific habitat projects started prior to 1989 as part of the Wildlife Habitat Mitigation Program. These include:

- an annual assessment of survival of trees planted in shelterbelts and nurseries in 1987 and 1988,
- a monitoring program for shrub encroachment from a coulee to upland native grass range following placement of a snow fence,
- a survey of effects of snow fence placement on soil moisture, and
- documentation of successional changes in a heavily grazed grassland now being protected.

The second section of this part is a description of and preliminary results for an experiment set up in 1989 to determine effects of snow fencing on above-ground biomass of native rangeland.

The second part of this report consists of plans and outlines for projects proposed for 1990 and 1991. Proposed projects include:

- audits of survival and growth of trees planted in 1989,
- an experiment to determine effects of four soil amendments on establishment of Douglas fir,
- an experiment to determine if snow fence placement has an effect on establishment of tree and shrub seedlings,
- field trials to test mixtures of native grasses and forbs in seeding trials, and
- a study of effects of grazing on species composition and above-ground biomass on rest-rotational native pasture.

The final subject of this report concerns production of native forbs and grasses (at AEC) which will be required for site specific reclamation at the Oldman River Dam. This section also includes a short note on forb and grass seeds collected in 1989 at the Oldman River Dam Site.

Botanical names are used throughout this report for native plants and the nomenclature follows Moss (1983). An Index of Common and Botanical Names is included in Appendix 1.

2 PROJECTS – 1989

2.1 Auditing existing mitigation projects

The primary purpose of auditing mitigation techniques at these sites was to provide information from which wildlife habitat increases can be calculated, to gain insight into the need for specific studies of particular problems, and to assist in future planning at this and similar sites.

2.1.1 Shelterbelt and nursery plantings

Snow fence placement and tree plantings were the beginning of the wildlife habitat mitigation project for the Oldman River Dam program. In 1987 and 1988 a major tree planting scheme was undertaken on a site east of the dam (Sec 21, Twp 7, Rg 29, W4M and Sec 16, Twp 7, Rg 29, W4M). Numerous snow fences were placed and behind (leeward of) them rows of subsurface drip irrigation were installed and trees planted along the irrigation lines to create shelterbelts. Most of the site had been previously cultivated and now has been seeded to native grasses and grass cover crops. Small areas closer to the valley bottom were not cultivated and remain as native grassland. Shelterbelt plantings were placed to stabilize the abandoned cultivated field and provide shelter for wildlife.

Survival of trees was not recorded in the first or second year. Since many more trees and shrubs are to be planted in the reservoir area in the next 2-3 years it is important to determine which tree and shrub species are surviving at this first planting site. The original planting plan, with the numbers of trees planted, was not available therefore in the summer of 1989 an initial count was made of trees which were in the field and the number of surviving trees. This initial count will be used from year to year to determine if mortality has leveled off or will continue to be a problem, or if one or several particular species posed a serious problem in establishment or survival.

Ten plots were set up to include all tree species used in the plantings. Plots were not uniform in size or shape rather they were chosen to include and represent all the plantings and areas. Within each plot a count was taken along each row of all of the trees and survival was recorded. The percentage of live trees (of those still in the ground) was calculated (Table 1).

This information can be used to make recommendations regarding tree species that might require further study, to identify problems regarding successful establishment and to recommend methodologies for setting up and monitoring plots from which statistically significant data can be collected. Since no count was made of the number of trees originally planted, and since some of the trees (e.g. Douglas fir) were replaced in the second year no comment can be made on overall survival.

One year old northwest poplar were planted in 1987 and 1988. Although most were planted in what was cultivated land, some were planted into native *Stipa/Agropyron* rangeland. Most poplar appeared vigourous, however there was some damage to newer shoots and some bark removal by deer. Poplar planted into the rangeland appeared healthier than those in the cultivated areas, likely because those in the rangeland were not competing with the fast-growing, weedy perennials for moisture and nutrients.

Apparently, most of the caragana (*Caragana arborescens*) planted at this site in 1987 did not survive the first year and many were replaced in 1988. When a count was taken in 1989, most caragana were alive, but some had severe insect damage especially those which were placed into the native grassland, or in areas where the planted grasses had become well established.

Colorado blue spruce (*Picea pungens 'glauca'*) planted in 1987 did not establish well and many had to be replaced in 1988. The 83% survival recorded in 1989 is somewhat misleading since many of these were in extremely poor condition. Further counts will determine if these recover.

Table 1. Survival of trees at nursery plots and shelterbelts in 1989.

Species	Survival (%)	Total Number of Indiv. Counted
Caragana	97	444
Northwest poplar	91	298
Colorado blue spruce	83	459
Douglas fir	33	3

Very few Douglas fir (*Pseudostuga menziesii*) were left at the site. In 1988 those that did not survive the first winter were replaced with spruce. Of those which survived most were only alive up to the level to which they are covered by snow in the winter months.

Both spruce and Douglas fir require protection from desiccation in winter and summer and require some protection from the intense sun in summer. These species would probably have an increased chance of surviving if they were planted after the establishment of deciduous trees.

The analyses of soil samples taken at the site are presented in Table 2. Samples 1-3 were collected in a previously cultivated area whereas samples 4 and 5 were collected from areas where trees were planted into native grassland.

Sample 4 was the only sample not deficient in nitrogen; all samples were deficient in phosphorus. The lack of nitrogen could be due to the large number of perennial weeds which inhabit the soils. A low nitrogen content is often found in soils which are poorly fallowed, heavily cropped, or low in organic matter. Two samples collected in relatively undisturbed areas had a greater amount of organic matter. In all samples however, the amount of organic matter was low. The pH of all samples was high especially for the growth of conifers (spruce and Douglas fir). The high level of free lime may lead to a reduction in the amount of nutrients available to the plants. The best method of reducing the free lime content in soils is to increase the amount of organic matter in the soil. The addition of organic matter also improves water holding capacity which would be beneficial at the dry Oldman site.

The use of exotic trees (caragana, Colorado blue spruce and northwest poplar) should be avoided since these are not adapted to the site, or to climatic conditions in the area. These will not blend into the landscape as readily as trees and shrubs which occur naturally in the region.

Table 2. Analysis of soil samples collected from nursery and shelterbelt plantings.

Sample Number	Nutrients N	P	K	S	Na	Con	pH	OM (%)	Free Lime	Texture
G-1	D	D	A	D	L	N	8.4-8.5	3.9-4.5	H/I	v. fine
G-2	D/M	D	A	M	L	N	8.3-8.5	3.4-4.8	H	v. fine
G-3	D	D	A	D	L	N	8.4-8.5	3.6-4.4	H	v. fine
G-4	A	D	A	M	L	N	8.3	5.2-6.9	H	medium – v. fine
G-5	D	D	A	D	L	N	8.3-8.4	4.7-5.8	H	medium – v. fine

N=nitrogen, P=phosphorus, K=potassium, S=sulphur, Na=sodium, Con=Conductivity, OM=Organic Matter; D=deficient, M=marginal, A=adequate, L=low, N=negligible, H=high, I=medium.

Although this area will be monitored over several years to determine which trees are establishing and what cover they are producing for wildlife, it is imperative that individual studies be set up immediately so variables which affect establishment can be studied independently. In following sections some of the problems of establishment will be addressed and specific studies designed for this purpose.

2.1.2 Snow fence effects on tree and shrub encroachment

Throughout the land base (acquired and maintained by PWSS), projects have been set up to enhance existing vegetation. Much of the enhancement is undertaken by strategic placing of snow fences to increase soil moisture and encourage shrub invasion.

Coulees, on the north side of the future reservoir and oriented north and south have limited numbers of trees and shrubs, most of which grow on the east face and in the bottom of the coulees where moisture collects. At the top edge of the coulee shrub communities are differentiated sharply from the grass community since there is no longer protection from the wind and soil moisture decreases.

Since shrubs and trees provide better cover and more food for wildlife than grasslands, snow fences were placed in the fall of 1988 (by PWSS) along the ridges between coulees to encourage encroachment of trees and shrubs from the coulee up onto the grassland at a site to the north and east in the protected land base (Sec 16, Twp 7, Rg 29, W4M). It was assumed that snow fences increase soil moisture and decrease wind allowing trees and shrubs to invade into the native grassland. The monitoring was undertaken at the request of PWSS.

In 1989 five transects were placed from a NW-SE fence at right angles to the edge of the coulee. Transects were of various length depending on the distance of the coulee from the fence. The length of each transect was determined by the distance from the fence to where over 25% of the vegetation cover was composed of trees and shrubs. Two transects were run in the area where there was snow fence, two were

placed in an area with no snow fence, one was placed in the area of transition between the snow fenced and unfenced areas. Permanent 1 m by 0.5 m plots were placed at the end of the transect and three similar plots were placed at 2 m distances toward the fence extending out of the shrub community into the grassland community. Each plot was monitored in mid-July by recording individual plant species and their percent cover.

Fences were set up to follow the ridge rather than be equidistant from the edge of the coulee therefore distance between the fence and the coulee varies. Due to this variation results must be interpreted with caution. If great differences are observed between the fenced and unfenced areas these would not necessarily be attributed to the fence, however if no differences are observed in tree and shrub growth and invasion it can be assumed that the fence had little or no effect.

Results of observations taken in mid-July are presented in Table 3. In each transect shrubs covered at least 25% of the plots farthest from the fence, and only in Transects A and B were shrubs observed in the second plots. *Symphoricarpos occidentalis* (buckbrush) was the only shrub which occurred in all plots containing shrubs. Other shrubs included *Amelanchier alnifolia* (Saskatoon), *Elaeagnus commutata* (wolf willow), *Crataegus rotundifolia* (round leaf hawthorne), and *Rosa arkansana* (prairie rose).

Plots will be monitored yearly and changes in shrub cover documented. Soil moisture will be measured if feasible in subsequent years and compared or related to observed changes in vegetation.

2.1.3 Soil moisture behind snow fences

Snow fencing was placed on a section of perimeter fencing at a site west of the Castle River and south of Highway 3 (Sec 11, Twp 7, Rg 1, W5M) in the fall of 1988. The primary purpose was to increase soil moisture levels such that trees and shrubs for wildlife mitigation could be planted with some reasonable expectation of

Table 3. Vegetation cover in plots where snow fence was placed to encourage invasion of shrubs from a coulee into the grassland.

Plot Number* (distance from fence line)	Shrubs (%)	Graminoids (%)	Forbs (%)
A-15m	0	26	5
A-17m	0	26	2
A-19m	3	19	3
A-21m	41	2	57
B-20m	0	9	13
B-22m	0	37	3
B-24m	18	21	6
B-26m	35	20	8
C-21m	0	11	16
C-23m	0	11	9
C-25m	0	6	22
C-27m	55	30	7
D-22m	0	35	17
D-24m	0	29	16
D-26m	0	45	15
D-28m	46	31	16
E-22m	0	12	25
E-24m	0	4	35
E-26m	0	9	36
E-28m	28	27	41

* A and B are snow fenced, C is in the transition zone and D and E are from areas with no snow fence.

successful establishment. The snow fence (it was assumed) would increase soil moisture in two ways; by trapping snow and enhancing the formation of drifts in winter and by reducing the amount of wind and therefore evaporation of moisture in the summer months. Snow fences were placed at intervals, and gaps were left to allow access to wildlife.

The existing, intermittent snow fence provided an opportunity to study effects of snow fence on soil moisture and provide site specific information for planning tree and shrub placement at this site in the near future. An experiment was set up to determine if significant differences could be detected in soil moisture among areas behind snow fences and areas where no snow fences were erected and if so, what were the effects on soil moisture at various depths and distances from the fence. Seasonal differences in soil moisture were determined by sampling in mid- and late summer.

Vegetation at the site was a mixture of native grasses, forbs, low shrubs, and introduced forage grasses and legumes. The area was used for cattle grazing up to the time of the first sampling. At that time fencing was put in place to exclude cattle.

Snow fencing was placed at intervals along a north-south fence line. Sections of snow fence were approximately 30 m with intervening gaps of approximately 13 m. Prevailing winds were from the southwest. The ground sloped away from the fence on the leeward side. The slope varied over the entire area from almost flat to a slope of approximately 45 degrees. Four fence sections and four intervals were chosen to include various slopes and aspects. Sample points were chosen in lines perpendicular to the fence line (on the leeward side or east) at intervals of 1 m, 2 m, 4 m, 8 m, 16 m, and 32 m. Soil samples were collected using a dutch hand auger at a point approximately 50 cm south (June) and 50 cm north (September) of the line at the given distances. Samples were taken from 5 depths: 0-15 cm, 15-30 cm, 30-45 cm, 45-60 cm, and 60-75 cm. Each sample was placed in an individual, labeled plastic bag and sealed. A number of the individual bags were placed in a

larger plastic bag and all samples were transported to the laboratory at Vegreville (AEC). Soil samples were weighed, placed in pre-weighed foil dishes and dried at 105° C for 24 hours in a drying oven. The oven-dried soil was then weighed and water loss calculated. Percent soil moisture was calculated using the following formula:

$$\frac{\text{Water loss (g)}}{\text{Sample Dry Weight (g)}} \times 100 = \text{Percent Soil Moisture}$$

Results were analyzed using an analysis of variance (ANOVA) and means were compared using the Duncan's Multiple Range Test (DMR).

Samples of soil from the 4 m sampling point at depths of 0-15 cm and 15-30 cm were placed in paper bags, air dried, and sent to the Soil and Feed Testing Laboratory of Alberta Agriculture to determine texture, soil pH, and nutrient levels. Soils in this area were fine textured clays with a pH of 8.2-8.5 (Appendix 2).

The ANOVA table presented in Table 4 includes mean squares for each primary factor and first order interaction. The single largest cause of variance was season, but each primary factor (fence, season, depth, and distance) had a significant effect on soil moisture. Interactions between season and fence and between fence and depth also contributed significantly to the variance. Other interactions (including three and four way interactions) were not significant.

Moisture content of the soil was considerably greater in early summer than in late summer (Table 5), reflecting the precipitation pattern (Appendix 3). Monthly precipitation increased from April until June and July and then decreased in August, September, and October (Environment Canada 1989). Dry, warm winds prevalent in this region in summer result in significant evaporation and probably account for some of this observed difference. Water uptake by vegetation during the growing season would also account for this observed difference in soil moisture.

The effect of the snow fences was the second greatest source of variance. Snow fences significantly increased soil moisture (Table 6); probably as a result of a

Table 4. Mean squares of each of the primary effects and the first order interactions for soil moisture.

Source	DF	Mean Square of Variance
Season	1	3123.59 ***
Fence	1	873.08 ***
Depth	4	312.70 ***
Distance	5	191.01 ***
Season*Fence	1	207.32 ***
Fence*Distance	5	63.18 **
Fence*Depth	4	34.74
Season*Distance	5	30.40
Season*Depth	4	17.11
Distance*Depth	20	7.53

*** significant at 0.1%;
** significant at 1%.

Table 5. Effect of season on soil moisture.

Season	Soil Moisture* Mean (%)
June	24.10 A
September	18.99 B

* Means followed by different letters are significantly different. (Duncan's Multiple Range Test).

Table 6. Effect of snow fencing on soil moisture.

Treatment	Soil Moisture* Mean (%)
Fenced	22.90 A
Unfenced	20.20 B

* Means followed by different letters are significantly different. (Duncan's Multiple Range Test).

combination of snow accumulation in winter and wind reduction throughout the year.

Soil samples were generally drier at greater depths. The driest samples were taken at 60-75 cm and soil samples contained more moisture at shallower depths up to 15-30 cm. Surface samples were drier than those at the 15-30 cm level. This lower moisture level at the surface was likely a result of surface evaporation. If trees are to be planted it will be necessary to monitor water content of the soil over a period of years to determine if the snow fence has a beneficial effect on accumulation of soil moisture at increasing depths.

Soil moisture means for the interaction between season and fence are presented in Figure 2. The amount of soil moisture lost over the season was greater in samples taken from behind snow fences (Figure 3) however, samples taken from behind snow fences had greater soil moisture means in June and September than samples taken in June and September from unfenced areas. This indicates that snow fencing resulted in a net accumulation of moisture even in the first season.

The interaction between snow fence and distance was significant. Although there was a general increase in soil moisture from 1 m to 32 m for all samples combined, the trend was much more obvious in unfenced samples (Figure 4). Figure 5 is a plot of the differences in soil moisture between fenced and unfenced samples at each of the six distances. The graph indicates that the greatest increases occurred at 2 m, 4 m, and 8 m. Even at 1 m a difference of approximately three percentage points was observed. A difference was not observed in samples taken at 16 m. There appears to be a critical distance at which moisture behind snow fences no longer increased. This critical distance lies between 8 m and 16 m, and future sampling should include at least one sampling point between these two (possibly at 12 m). There was a slightly smaller effect of the snow fence at 32 m. This suggests that there was a second, smaller snow accumulation area.

Figure 2. Effects of snow fencing and season on soil moisture.

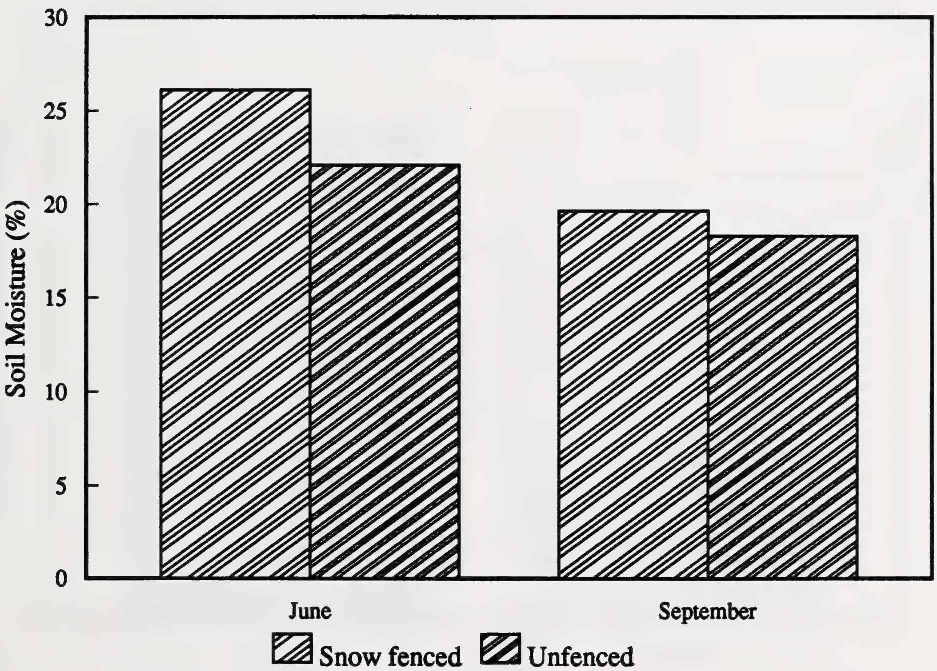


Figure 3. Differences in soil moisture between snow fenced and unfenced areas in June and September.

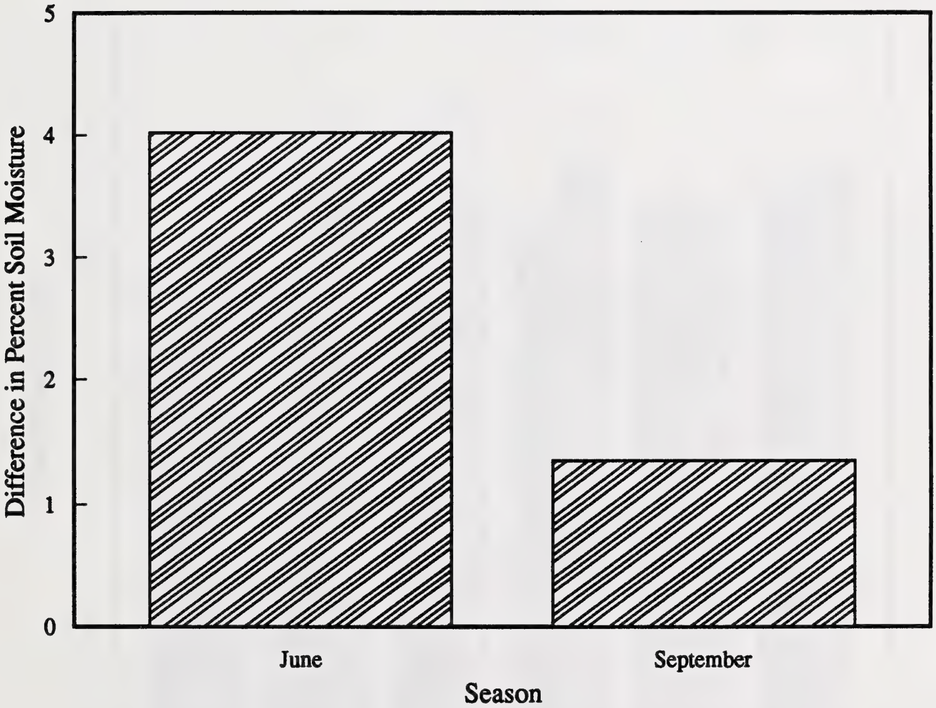


Figure 4. Effects of snow fences on soil moisture at six distances from the fence line.

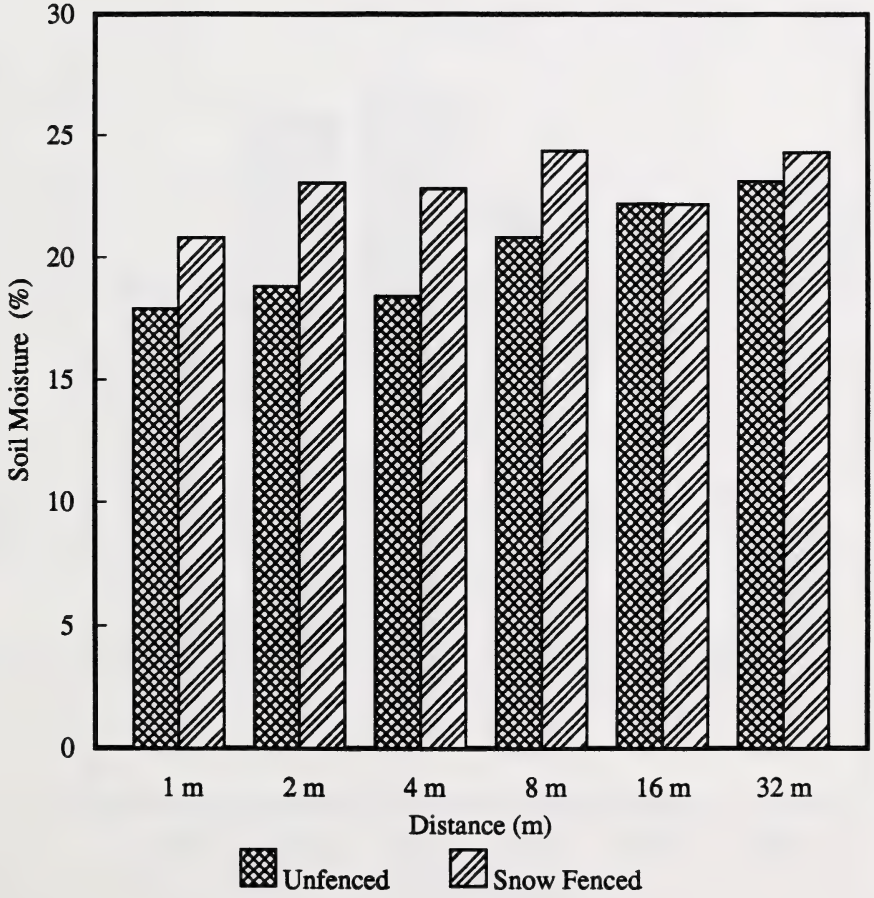
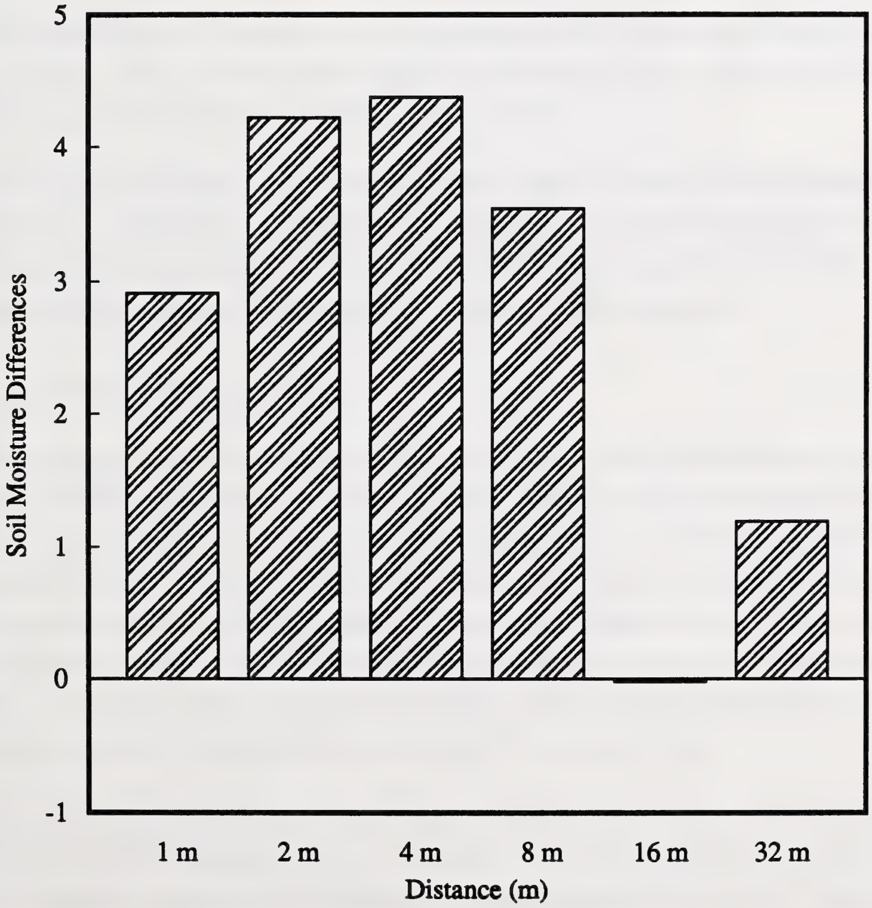


Figure 5. Differences in soil moisture between snow fenced and unfenced areas.



Since slope was not taken into account in this experiment differences in soil moisture at various distances are valid for this site and very similar sites, however caution must be exercised in extrapolating these results to sites which are relatively flat or which slope in different directions or at different angles. An experiment being set up to observe effects of snow fence on productivity of native grassland (Section 2.2.1) will include a study of the soil moisture in front of and behind snow fences on a relatively flat area.

Soil moisture will continue to be measured and changes documented over several seasons. Of specific interest will be changes in the interactions between snow fences and each of depth, distance, and season.

Plantings at similar sites close by which will be made in 1990 should be designed based on these results. Plantings should be placed behind snow fences and at distances of 2-8 m from the fences. To take advantage of the improved soil moisture planting should be undertaken in spring and early summer.

2.1.4 Grassland recovery

Protecting wildlife habitat by excluding cattle is one method being used extensively for wildlife mitigation. One of the areas being protected is a section of *Agropyron/Stipa* community (Sec 32, Twp 7, Rg 1, W5M) which had been heavily grazed in past years. To accurately assess increases in wildlife habitat, changes in vegetation must be documented. Of particular interest are species composition and relative abundance of each species and changes in these over a period of years. To this end, cattle were excluded and plots were set up in an area of grassland such that an annual monitoring program could be put in place.

Six plots, each measuring 2 m by 2 m, were permenently marked with metal pegs in a relatively flat grassland area. Records were taken in mid-July (July 18-19, 1989). All vascular plants were identified and their presence recorded. Relative abundance of each species in each plot was recorded as an estimation of percent cover (Table 7).

Table 7. Species abundance in grassland recovery plots.

Species	Cover (%)*					
	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6
GRAMINOIDS						
Agropyron smithii	t	10	10	10	30	15
Agropyron spicatum	2	–	–	–	t	1
Bouteloua gracilis	–	5	–	5	2	1
Carex filifolia	–	–	–	–	2	1
Carex sp.	–	5	3	5	1	1
Koeleria macrantha	–	1	–	–	–	–
Stipa comata	20	8	20	10	2	10
FORBS						
Achillea millefolium	t	–	1	–	–	t
Allium cernuum	–	t	–	–	t	–
Anemone patens	t	–	t	–	–	–
Antennaria parvifolia	30	5	–	10	2	2
Artemisia campestris	–	–	–	–	t	–
Artemisia frigida	10	15	6	5	10	5
Aster ericoides	–	4	2	5	2	1
Aster laevis	1	–	1	–	–	–
Astragalus flexuosus	–	–	–	t	–	t
Comandra pallida	–	–	–	–	t	t
Cryptantha sp.	–	t	–	–	–	–
Erigeron caespitosus	–	t	–	–	–	–
Gaillardia aristata	–	t	–	t	t	–
Galium boreale	1	–	t	–	1	–
Geum triflorum	–	3	10	t	–	t
Heterotheca villosa	t	2	t	–	–	t
Heuchera parvifolia	t	–	–	t	–	t
Liatris punctata	2	2	–	t	t	–
Lithospermum ruderale	3	–	2	t	10	2
Orthocarpus luteus	–	–	t	–	t	–
Oxytropis monticola	t	t	–	–	–	–
Petalostemon purpureum	t	1	–	–	–	–
Phlox hoodii	1	–	5	5	t	–
Potentilla hippiana	t	–	–	–	–	–
Potentilla pensylvanica	t	–	t	–	–	–
Senecio canus	–	–	–	t	–	t
Solidago missouriensis	–	–	10	–	3	–
Sphaeralcea coccinea	–	–	–	–	–	1
Taraxacum officinale	t	–	–	–	–	–
Vicia americana	t	–	t	t	–	t
SHRUBS						
Rosa arkansana	t	t	3	2	2	–
Symphoricarpos occidentalis	–	–	20	–	–	–

* t = <1% cover

Graminoids (5 grass species and two *Carex* species) covered 22-37% of the plots. There was a greater diversity of forbs, however relative abundance for the forbs ranged between 11-47%. Shrubs covered a very small percentage (0-2%) of most of the plots except for plot 4 (on a shallow, north-facing slope) where shrubs (*Symphoricarpos occidentalis* and *Rosa arkansana*) covered 23%.

2.2 New projects

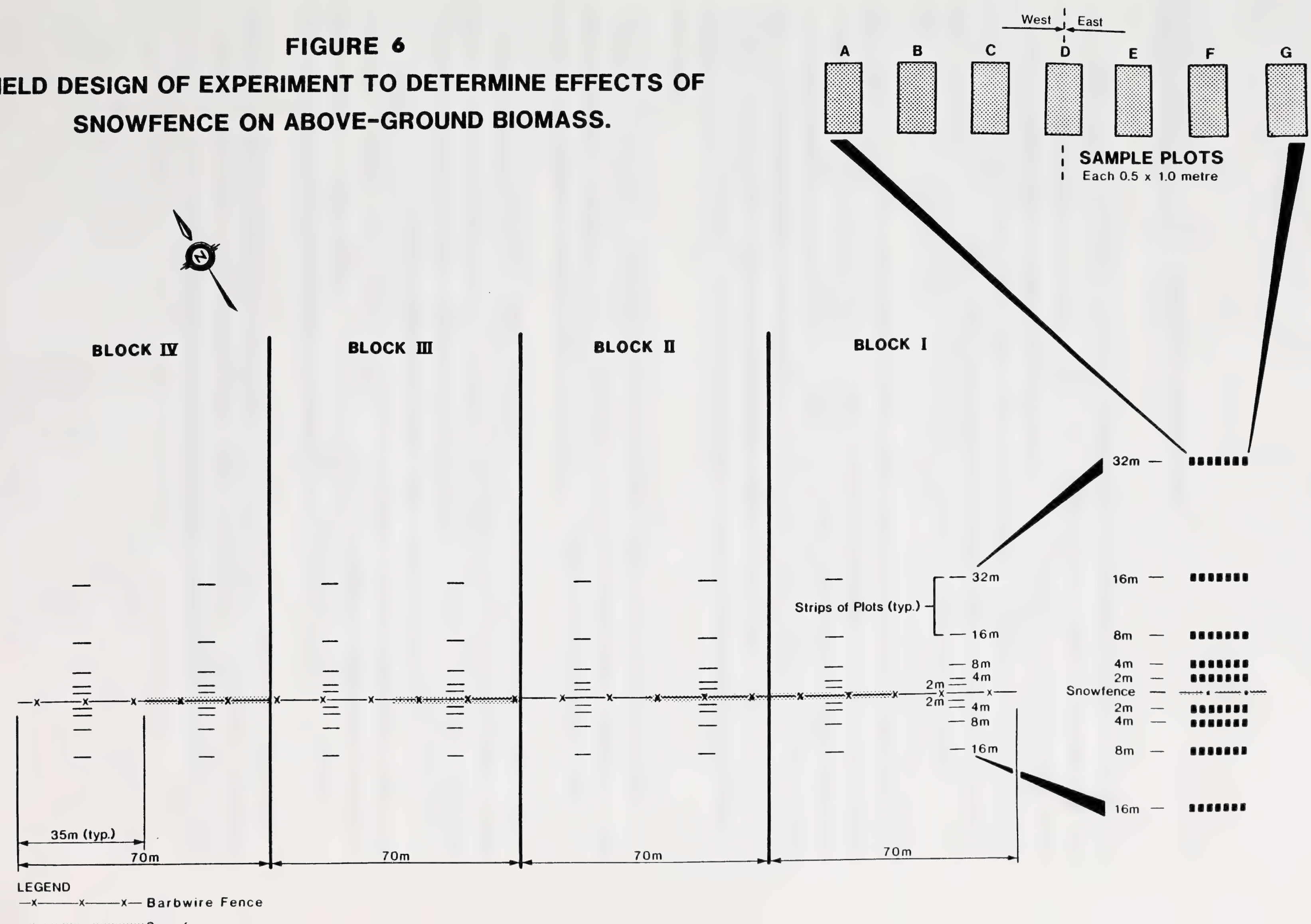
2.2.1 Grassland restoration

A second study on recovery of grasslands was set up at a site north of the future reservoir (Sec 33, Twp 7, Rg 1, W5M). The object of this study was to determine effects of snow fencing on recovery of heavily grazed *Agropyron / Koeleria / Stipa* community when grazing ceased.

A barbed-wire fence of approximately 300 metres was installed in a WNW-ESE direction (perpendicular to the prevailing winds) in an area of relatively flat, heavily grazed rangeland. The site was chosen after a visual inspection determined that it was relatively uniform in topography and vegetation cover. A 3-factor split, split plot design was set up with four replicates (blocks) placed along the fence line. Each block consists of 70 m of fence which was divided into two sections one had snow fence placed on it in October 1989 (fenced), the other 35 m was left open (unfenced). Fenced and unfenced areas were assigned randomly within blocks. Strips of plots (7 m long and 1 m wide) were placed leeward of, and parallel to the fence line. Each strip consisted of seven plots each 1 m by 0.5 m arranged side by side with an intervening gap of 0.5 m. Strips were placed at distances of 2 m, 4 m, 8 m, 16 m, and 32 m from the fence line. A similar arrangement of strips/plots was set up to the windward side of the fence, however only four strips of plots were placed at distances of 2 m, 4 m, 8 m, and 16 m (Figure 6). Each plot within a strip was assigned randomly either as a control, or to be clipped for biomass measurement in each of the following years, 1989, 1990, 1991, 1992, 1993, and

FIGURE 6

FIELD DESIGN OF EXPERIMENT TO DETERMINE EFFECTS OF SNOWFENCE ON ABOVE-GROUND BIOMASS.



1994. After all plots had been set up and assigned a treatment they were monitored for species composition, relative abundance, and above-ground biomass in the following manner. Each grass and forb species was identified and the percent cover of each species was recorded in each of the control plots. The above-ground biomass was measured in the 1989 plot by clipping all plants growing in the plot to ground level. Clippings of each species were placed in separate, labeled paper bags.

Samples were dried at 30° C until no more weight loss was observed (approximately 1 week), and the dry weight was recorded. This same procedure will be undertaken in each of the following five years, with a randomly selected plot being clipped for above-ground biomass determinations each year, and a constant area being monitored for species composition and relative abundance. Snow fences were placed following data collection. Above-ground biomass data were analysed by analysis of variance.

Relative abundance and presence and absence data will be used in future. A determination of improvement can be made based on presence and absence, or the increase or decrease of specific indicator plants as outlined in Wroe et al. (1981).

The above-ground biomass data collected in 1989 were analyzed to determine if there was significant variation among treatments prior to the snow fences being placed and as a control for differences which might be observed in following years. The analysis of variance determined that there was no significant variation in biomass among blocks or among areas which are to have snow fence and areas which are to be left unfenced. There was also no significant difference in the above ground biomass at various distances or in either direction from the fence line.

Results of species composition and relative abundance are presented in Appendix 4. A comparison with results from future years will provide a guide to changes in vegetation and assist in determining effects of snow fences at various distances and in each direction.

3 PROPOSED PROJECTS - 1990-1991

A number of projects are proposed for 1990 and 1991 and these will provide much needed information concerning various aspects of vegetation establishment which relate directly to the success of the Wildlife Habitat Mitigation Program at the Oldman River Dam Site. There are again two types of projects; the first consists of monitoring or auditing existing plantings and methods of enhancement; the second involves setting up experiments to obtain significant baseline data on specific aspects of vegetation establishment. Among the latter are experiments designed to provide information on tree and shrub establishment, experiments designed to determine success of upland seeding mixtures of native grasses and forbs, and an intensive study of effects of grazing on biomass production on native rangeland.

3.1 Auditing existing mitigation projects

3.1.1 Survival of 1989 plantings

Several plantings were made at various mitigation projects in 1989. A representative number will be chosen in cooperation with all planners on-site. Plots will be set up and monitored over the long term for survival and growth. Results will be used in further planning for future plantings and in decisions regarding supplemental plantings and re-planning.

3.2 New projects and experiments

3.2.1 Fertilizer effects on Douglas fir establishment

Plans for replanting various areas at the Oldman River Dam include the planting of Douglas fir. These native trees provide extremely good winter cover for the mule deer populations which inhabit the region (J. Green, personal communication).

Establishment of Douglas fir seedlings however has been problematical (see Section 2.1.1). Factors which could account for the failure of Douglas fir seedlings to establish include availability of water, lack of protection, and soil type (extremely high soil pH, low levels of nitrogen, phosphorus, and sulphur, high free lime content and the low percentage of organic matter). Water problems can be alleviated by installing irrigation where necessary and by planting in areas where water is more readily available such as lower levels of north facing slopes. Protection of seedlings from drying winds especially in winter can be accomplished by careful placement of snow fences and by placing Douglas fir on lower slopes away from extreme winds. Soils can be amended or manipulated in various ways to decrease pH and the level of free lime and increase amounts of nutrients and organic matter however many products or methods are expensive or labour intensive. There are a number of soil amendments readily available which have been proposed as soil amendments in planting projects on site (A. Nilson, personal communication). An experiment is being designed to determine whether any of four, locally available amendments (sewage sludge, composted manure, sulphur, and soil from native conifer communities) will improve survival and growth of Douglas fir seedlings planted into native grassland at a site north of the proposed reservoir (Sec 34, Twp 7, Rg 30, W4M).

The design will be a completely randomized block and will be analysed using analysis of variance. Irrigation and protection will be provided since only soil amendments will be tested.

3.2.2 Effects of snow fence on tree and shrub establishment

Success of the Wildlife Habitat Mitigation Program will depend on rapid establishment of native trees and shrubs at sites throughout the land base. One of the greatest obstacles to establishment of trees and shrubs is the lack of water available to plants especially in the year or two immediately after planting. Snow fencing is an inexpensive method to increase soil moisture and is being used extensively at the Oldman project. An experiment is being designed to determine if

snow fences will significantly increase establishment potential of four tree and shrub species (planted into an open grassland area), and if an increase is observed, if there is an optimum distance from snow fences for these to be planted. Secondarily, this experiment will provide information concerning which tree and shrub species grow best with and without the benefit of snow fences.

A fence of 100 m was placed in an open grassland north of the proposed reservoir (Sec 34, Twp 7, Rg 30, W4M) in the fall of 1989. This fence will be divided into 2 replicates of 50 m each. Each replicate will be divided into two and each half will be randomly chosen for snow fencing placement or to remain open. Within each half replicate (fenced or unfenced section) the area will be divided in half perpendicular to the original fence. Two sets of four lines of trees, planted parallel to the fence and at intervals of one metre, will constitute a block. Blocks will be repeated six times (up to 24 m) from the fence line. Each row within a block will consist of only one species and each species will be represented in each half replicate. Rows will be randomized within each block.

Trees will be planted in the spring of 1990 and monitored annually for survival, growth (height), and vigour (on a subjective scale of 1-5). Data will be analysed using an analysis of variance for a randomized complete block design.

3.2.3 Establishment of grasses and forbs

Several areas within the land base around the Oldman River Dam were cultivated and now must be reseeded with native range plants which will not only establish quickly and provide cover for erosion control and soil stability but must also provide wildlife with habitat (food and shelter). Past efforts in this regard have not been very successful (Nilson, personal communication) at the Oldman River Dam Site. New seeding mixtures have been recommended by those working on the Wildlife Habitat Mitigation Program and these will be tested. The specific area in which testing will occur has not yet been determined and an experimental design is still being developed.

3.2.4 Effects of grazing on biomass in native rangeland.

A particular concern for management of the newly acquired land base is continued use of grasslands by area ranchers. It is felt by PWSS that managed grazing could continue at specific sites and that a managed grazing program would be beneficial to the maintenance of grasslands (A. Nilson, personal communication). Prior to making decisions regarding the use of specific areas, information must be available on effects of grazing on production of these native rangelands.

A study will be proposed to determine these effects such that a well managed land use program, one which will benefit both wildlife and local ranchers, can be set up.

4 SEED PRODUCTION

4.1 Existing resources (AEC)

Reclamation and revegetation with native plants is often restricted in Alberta because of the lack of native plant material, and a poor understanding of propagation methods and establishment techniques. The demand for large quantities of seeds of native forbs will increase as more wildlife habitat mitigation projects are undertaken at the Oldman River Dam Site and at sites throughout Alberta. Most native forbs were not available through commercial sources but small amounts of seeds were in storage at AEC from previous joint projects undertaken with Operations and Maintenance of Alberta Environment and seeds of some species were available from stores kept at PWSS also from previous projects. To prepare for an increased demand, stored seeds were tested for germinability, and sown in the greenhouse at AEC in the summer and placed in field plots in the fall prior to freeze-up. These will begin to produce seeds in 1990. Seeds will be available either for large scale seed multiplication or for using in small projects on site at the Oldman River Dam Project. AEC will continue to retain stocks of seeds at their Native Plant Genetic Resources Laboratory and these will be renewed regularly.

Germination tests were conducted with 37 species of forbs considered to have some value for seeding projects at the Oldman River Dam Wildlife Mitigation Program. Seeds from AEC had been harvested from field plots at Vegreville in 1983 and 1984 cleaned and stored dry at room temperature. Seeds from PWSS had been collected in the wild and stored since 1983 in refrigerated units at ambient humidity. Some of the AEC seeds had been tested for germination in previous years but most had not been tested for several years. The purpose of testing germination was to determine if seed lots had sufficient viability for field plantings.

Germination tests for each seed lot consisted of four replicates of 25 seeds each. Seeds were placed in petri dishes on Whatman #1 filter paper and moistened with sterile water. Dishes were placed in a germination chamber set at 25° C for 16 hrs (light) and at 15° C for 8 hours in the dark. Sterile distilled water was added as required. A few drops of Vitavax (fungicide) were added to dishes where necessary to control fungus. Germination (considered complete when the radicle emerged from the testa) was counted three times weekly for a period of 30 days and germinants were removed. Seeds of all legumes were scarified using 100 grit sandpaper prior to germination testing.

Table 8 lists germination results for stored seeds. It is noteworthy that germination within some seed lots varied from June to November. It would be interesting to investigate these discrepancies to determine if the variation is seasonal.

In July approximately three hundred seeds of 26 species were sown (one per cell) in Hillson 6 root trainers filled with a standard soil mix of one part each of loam, peat, sand, and vermiculite with dolomite lime and phosphorus added at a rate of approximately 15 ml/100 l. Trays of root trainers were placed on a draining bench in the greenhouse and kept at temperatures of 22° C for 16 hrs during the day under natural and enhanced lighting and at 10° C in the dark at night. Water was added as required and plants were fertilized with a complete fertilizer (20-20-20) once prior to being transplanted outdoors. Seedlings of legumes were extremely susceptible to damp-off and watering was tailored to individual plants. In late August and early September seedlings were placed outdoors to harden off and in September and October plants were moved to a field plot. Double rows were placed at a distance of 50 cm apart and plants within a row were placed at 25 cm apart. Each set of double rows were placed 1 m from the next set of double rows. Seed harvesting should begin in 1990. A list of plant species which were placed in the field is included in Appendix 5.

Table 8. Germination of forb seeds stored at AEC and PWSS.

Forb Species	Germination (%)		
	June (AEC)*	November (AEC)*	November (PWSS)**
Achillea millefolium	90	71	38
Anemone cylindrica	–	0	–
Anemone multifida	12	0	–
Anemone patens	–	–	0
Arnica fulgens	48	–	–
Astragalus bisulcatus	46	87	–
Astragalus flexuosus	–	84	–
Astragalus striatus	35	91	–
Astragalus tenellus	–	31	–
Campanula rotundifolia	14	0	–
Erigeron glabellus	72	5	0
Gaillardia aristata	86	82	5
Geranium viscossissimum	–	3	–
Geum allepicum	–	100	23
Geum triflorum	82	14	0
Glycyrrhiza lepidota	–	95	–
Grindelia squarrosa	71	17	0
Haplopappus lanceolatus	–	–	0
Haplopappus spinulosus	41	9	0
Hedysarum alpinum	4	9	–
Hedysarum sulphurescens	–	22	–
Heterotheca villosa	33	8	0
Hymenoxys richardsonii	79	93	9
Liatris punctata	41	36	–
Monarda fistulosa	–	82	48
Oenothera nuttallii	–	66	–
Oenthera biennis	31	1	–
Oxytropis monticola	20	77	–
Oxytropis splendens	26	86	–
Penstemon nitidus	14	2	–
Penstemon procerus	–	0	0
Petalostemon candidum	43	25	–
Potentilla gracilis	–	78	59
Ratibida columnifera	76	47	0
Senecio canus	51	3	–
Solidago rigida	56	8	0
Thermopsis rhombifolia	–	–	26

* seeds stored dry at room temperature since 1983-84.
** seeds stored at 1-6° C since 1983-84.

4.2 Site specific seed collection

It was originally recommended that stocks of seeds be collected on site and these be used for sowing at various projects on site (Hardy and Associates (1978) Ltd, 1986.). There are two obstacles to this plan: i. often large quantities of seeds cannot be gathered on site, and ii. in studies of certain native grasses it has been found that seeds collected in the wild often have extreme dormancies and do not germinate as quickly or as completely as seed lots grown in a field nursery (Hermesh 1990). Therefore seeds of 21 forbs and grasses (including several which were recommended for use at sites at the Oldman River Dam (Appendix 6)) were collected by hand throughout the season by placing dried stocks and seed bearing structures in paper bags and air drying. Seeds were cleaned by various methods and preliminary germination tests were undertaken (as described in Section 3.1.1.). These forbs will be sown in the greenhouse in the spring and be transplanted into the field plots in early summer. Seeds from these forbs will be used for the same purpose as those which were stored at AEC (Section 3.1.1).

A complete list of seed collection for 1989 is included in Appendix 7. Table 9 presents preliminary germination results for these seeds.

The Vegetation Branch of AEC has an ongoing program to select, test and license native grasses for use in reclamation on the east slopes of the Rocky Mountains. The availability of seeds of native forbs provides an perfect opportunity to begin to include these in the ongoing program. Interest has been expressed in such a program by personnel of AEC and by numerous persons involved in reclamation in Alberta. A formal project should be established with AEC to incorporate some of these forbs into their ongoing program to select and license native plant varieties for reclamation. Further work should include some studies of germination and documentation of methods for harvesting, cleaning, and storing forb seeds.

Table 9. Germination of forb and grass seeds collected in summer of 1989 from the Oldman River Dam Site and tested in December.

Collection Number*	Species	Germination (%)
31	*Astragalus bisulcatus*	92
31	*Astragalus bisulcatus*	100
2	*Astragalus flexuosus*	60
20	*Astragalus flexuosus*	66
22	*Astragalus flexuosus*	100
4	*Astragalus missouriensis*	100
13	*Astragalus missouriensis*	98
44	*Artemisia frigida*	37
1	*Balsamorhiza sagittata*	2
8	*Balsamorhiza sagittata*	0
42	*Clematis ligusticifolia*	0
26	*Elymus piperii*	4
21	*Elymus piperii*	4
29	*Eriogonum flavum*	61
17	*Eriogonum flavum*	46
32	*Galium boreale*	4
33	*Galium boreale*	4
37	*Helianthus annuus*	0
41	*Liatris punctata*	94
18	*Linum lewisii*	12
25	*Linum lewisii*	21
10	*Linum lewisii*	5
3	*Lupinus sericeus*	62
1	*Mirabilis hirsuta*	0
23	*Oxytropis monticola*	100
36	*Oxytropis splendens*	98
15	*Penstemon nitidus*	0
27	*Penstemon nitidus*	2
27	*Penstemon nitidus*	0
28	*Potentilla hippiana*	48
14	*Potentilla pensylvanica*	70
12	*Sphaeralcea coccinea*	5
24	*Sphaeralcea coccinea*	23
35	*Thermopsis rhombifolia*	49
5	*Thermopsis rhombifolia*	59

* see Appendix 7 for collection information.

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APPENDIX 1. Common/botanical and botanical/common name index.

Common Name	Botanical Name
Alum-root	*Heuchera parvifolia* Nutt.
American Sweetbroom	*Hedysarum alpinum* L.
Arnica	*Arnica fulgens* Pursh
Ascending Milk Vetch	*Astragalus striatus* Nutt.
Balsam-root	*Balsamorhiza sagittata* (Pursh)Nutt.
Bastard Toadflax	*Comandra umbellata* (L.)Nutt.
Bladder-pod	*Lesquerella arenosa* S. Wats.
Blue Grama,Buffalo Grass	*Bouteloua gracilis* (H.B.K.)Lag.
Bluebell	*Campanula rotundifolia* L.
Bluebunch Wheat Grass	*Agropyron spicatum* (Pursh)Scribn.&Smith
Boreal Sweetbroom	*Hedysarum boreale* Nutt.
Broomweed	*Gutierrezia sarothae* (Pursh)B.&R.
Buckbrush	*Symphoricarpos occidentalis* Hook.
Canada Goldenrod	*Solidago canadensis* L.
Caragana	*Caragana arborescens* Lam.
Clustered Broom-rape	*Orobanche fasiculata* Nutt.
Colorado Blue Spruce	*Picea pungens 'glauca'*
Colorado Rubber-plant	*Hymenoxys richardsonii* (Hook.)Cockerell
Common Annual Sunflower	*Helianthus annuus* L.
Common Tall Sunflower	*Helianthus nuttallii* T.&G.
Cryptantha	*Cryptantha* sp.
Cut-leaved Anemone	*Anemone multifida* Poir.
Dandelion	*Taraxacum officinale* Weber
Douglas Fir	*Pseudostuga menziesii* (Mirb.)Franco
Dotted Blazing-star	*Liatris punctata* Schreb.
Early Cinquefoil	*Potentilla concinna* Richards.
False Dandelion	*Agoseris glauca* (Pursh)Raf.
Field Sage	*Artemisia campestris* Nutt.
Gaillardia	*Gaillardia aristata* Pursh
Giant Wild Rye	*Elymus piperi* Bowden
Golden Aster	*Heterotheca villosa* (Pursh)Shinners
Golden Bean	*Thermopsis rhombifolia* (Nutt.)
Goldenrod	*Solidago missouriensis* Nutt.
Goosefoot;Pigweed	*Chenopodium* sp.
Graceful Cinquefoil	*Potentilla gracilis* Dougl.
Green Needle Grass	*Stipa viridula* Trin.
Grey Tansy Mustard	*Descurania* sp.
Gumweed	*Grindelia squarrosa* (Pursh)Dunal
Indian Bread-root	*Psoralea esculenta* Pursh
Indian Rice Grass	*Oryzopsis hymenoides* (R.&S.)Ricker
June Grass	*Koeleria macrantha* (Ledeb.)J.A. Schultes f.

APPENDIX 1. Common/botanical and botanical/common name index.

Common Name	Botanical Name
Lance-leaved Pyrrocoma	*Haplopappus lanceolatus* (Hook.)T.&G.
Late Yellow Loco-weed	*Oxytropis monticola* A. Gray
Long-fruited Anemone	*Anemone cylindrica* A. Gray
Missouri Milk Vetch	*Astragalus missouriensis* Nutt.
Moss Phlox	*Phlox hoodii* Richards.
Mouse-ear Chickweed	*Cerastium arvensis* L.
Muhly Grass	*Muhlenbergia cuspidata* (Torr.)Rydb.
Needle & Thread Grass	*Stipa comata* Trin.&Rupr.
Night-flowering Catchfly	*Silene noctiflora* L.
Nodding Onion	*Allium cernuum* Roth
Northern Bedstraw	*Galium boreale* L.
Northwest Poplar	*Populus* hybrid
Old Man's Whiskers	*Geum triflorum* Pursh.
Owl-clover	*Orthocarpos luteus* Nutt.
Pasture Sage	*Artemisia frigida* Willd.
Pensylvania Cinquefoil	*Potentilla pensylvanica* L.
Pepper Grass	*Lepidium* sp.
Perennial Lupine	*Lupinus sericeus* Pursh
Prairie Aster	*Aster ericoides* L.
Prairie Cinquefoil	*Potentilla hippiana* Lehm.
Prairie Cone-flower	*Ratibida columnifera* (Nutt.)Wooten&Standl.
Prairie Crocus	*Anemone patens* L.
Prairie Groundsel	*Senecio canus* Hook.
Prairie Rose	*Rosa arkansana* Porter
Prairie Sage	*Artemisia ludoviciana* Nutt.
Prickly Pear	*Opuntia polycantha* Haw.
Puccoon	*Lithospermum ruderale* Lehm.
Purple Milk Vetch	*Astragalus vexilliflexus* Sheldon
Purple Prairie Clover	*Petalostemon purpureum* (Vent.)Rydb.
Pussy-Toes;Everlasting	*Antennaria parvifolia* Nutt.
Rough Fescue	*Festuca scabrella* Torr.
Round Leaf Hawthorne	*Crataegus rotundifolia* Moench
Salt Grass	*Distichlis stricta* (Torr.)Rydb.
Saskatoon	*Amelanchier alnifolia* Nutt.
Scarlet Mallow	*Sphaeralcea coccinea* (Pursh.)Rydb.
Sedge	*Carex* sp.
Showy Loco-weed	*Oxytropis splendens* Dougl.
Skunk-bush	*Rhus trilobata* Nutt.
Slender Blue Beard-tongue	*Penstemon procerus* Dougl.
Slender Milk Vetch	*Astragalus flexuosus* Dougl.

APPENDIX 1. Common/botanical and botanical/common name index.

Common Name	Botanical Name
Smooth Aster	*Aster laevis* L.
Smooth Blue Beard-tongue	*Penstemon nitidus* Dougl.
Smooth Brome Grass	*Bromus inermus* Leyss.
Smooth Fleabane	*Erigeron glabellus* Nutt.
Spiny Ironplant	*Haplopappus spinulosus* (Pursh) DC.
Sticky Purple Geranium	*Geranium viscosissimum* Fisch.&Mey
Stiff Goldenrod	*Solidago rigida* L.
Thistle	*Cirsium* sp.
Thread-leaved sedge	*Carex filifolia* Nutt.
Timothy	*Phleum pratense* L.
Townsendia	*Townsendia exscapa* (Richards.)Porter
Tufted Fleabane	*Erigeron caespitosus* Nutt.
Two-grooved Milk Vetch	*Astragalus bisulcatus* (Hook.)A. Gray
Umbrellawort	*Mirabilis hirsuta* (Pursh)MacM.
Western Clematis	*Clematis ligusticifolia* Nutt.
Western Wheat Grass	*Agropyron smithii* Rydb.
White Evening Primrose	*Oenothera nuttallii* Sweet
White Milk Vetch	*Astragalus tenellus* Pursh
White Prairie Clover	*Petalostemon candidum* (Willd.)Michx.
Wild Bergamot	*Monarda fistulosa* L.
Wild Blue Flax	*Linum lewisii* Pursh
Wild Licorice	*Glycyrrhiza lepidota* (Nutt.)Pursh
Wild Strawberry	*Fragaria virginiana* Duchesne
Wild Vetch	*Vicia americana* Muhl.
Wolf Willow	*Elaeagnus commutata* Bernh.
Yarrow	*Achillea millefolium* L.
Yellow-bell	*Fritillaria pudica* (Pursh)Spreng.
Yellow Avens	*Geum allepicum* Jacq.
Yellow Evening Primrose	*Oenothera biennis* L.
Yellow Hedysarum	*Hedysarum sulphurescens* Rydb.
Yellow Umbrella Plant	*Eriogonum flavum* Nutt.

APPENDIX 1. Common/botanical and botanical/common name index.

Botanical Name	Common Name
Achillea millefolium L.	Yarrow
Agoseris glauca (Pursh)Raf.	False Dandelion
Agropyron smithii Rydb.	Western Wheat Grass
Agropyron spicatum (Pursh)Scribn.&Smith	Bluebunch Wheat Grass
Allium cernuum Roth	Nodding Onion
Amelanchier alnifolia Nutt.	Saskatoon
Anemone cylindrica A. Gray	Long-fruited Anemone
Anemone multifida Poir.	Cut-leaved Anemone
Anemone patens L.	Prairie Crocus
Antennaria parvifolia Nutt.	Pussy-Toes;Everlasting
Arnica fulgens Pursh	Arnica
Artemisia campestris Nutt.	Field Sage
Artemisia frigida Willd.	Pasture Sage
Artemisia ludoviciana Nutt.	Prairie Sage
Aster ericoides L.	Prairie Aster
Aster laevis L.	Smooth Aster
Astragalus bisulcatus (Hook.)A. Gray	Two-grooved Milk Vetch
Astragalus flexuosus Dougl.	Slender Milk Vetch
Astragalus missouriensis Nutt.	Missouri Milk Vetch
Astragalus striatus Nutt.	Ascending Milk Vetch
Astragalus tenellus Pursh	White Milk Vetch
Astragalus vexilliflexus Sheldon	Purple Milk Vetch
Balsamorhiza sagittata (Pursh)Nutt.	Balsam-root
Bouteloua gracilis (H.B.K.)Lag.	Blue Grama, Buffalo Grass
Bromus inermus Leyss.	Smooth Brome Grass
Campanula rotundifolia L.	Bluebell
Caragana arborescens Lam.	Caragana
Carex filifolia Nutt.	Thread-leaved sedge
Carex sp.	Sedge
Cerastium arvensis L.	Mouse-ear Chickweed
Chenopodium sp.	Goosefoot;Pigweed
Cirsium sp.	Thistle
Clematis ligusticifolia Nutt.	Western Clematis
Comandra umbellata (L.)Nutt.	Bastard Toadflax
Cryptantha sp.	Cryptantha
Descurania sp.	Grey Tansy Mustard
Distichlis stricta (Torr.)Rydb.	Salt Grass
Elaegnus commutata Bernh.	Wolf Willow
Elymus piperi Bowden	Giant Wild Rye
Erigeron caespitosus Nutt.	Tufted Fleabane
Erigeron glabellus Nutt.	Smooth Fleabane

APPENDIX 1. Common/botanical and botanical/common name index.

Botanical Name	**Common Name**
Eriogonum flavum Nutt.	Yellow Umbrella Plant
Festuca scabrella Torr.	Rough Fescue
Fragaria virginiana Duchesne	Wild Strawberry
Fritillaria pudica (Pursh)Spreng.	Yellow-bell
Gaillardia aristata Pursh	Gaillardia
Galium boreale L.	Northern Bedstraw
Geranium viscosissimum Fisch.&Mey.	Sticky Purple Geranium
Geum allepicum Jacq.	Yellow Avens
Geum triflorum Pursh.	Old Man's Whiskers
Glycyrrhiza lepidota (Nutt.)Pursh	Wild Licorice
Grindelia squarrosa (Pursh)Dunal	Gumweed
Gutierrezia sarothae (Pursh)B.&R.	Broomweed
Haplopappus lanceolatus (Hook.)T.&G.	Lance-leaved Pyrrocoma
Haplopappus spinulosus (Pursh) DC.	Spiny Ironplant
Hedysarum alpinum L.	American Sweetbroom
Hedysarum boreale Nutt.	Boreale Sweetbroom
Hedysarum sulphurescens Rydb.	Yellow Hedysarum
Helianthus annuus L.	Common Annual Sunflower
Helianthus nuttallii T.&G.	Common Tall Sunflower
Heterotheca villosa (Pursh)Shinners	Golden Aster
Heuchera parvifolia Nutt.	Alum-root
Hymenoxys richardsonii (Hook.)Cockerell	Colorado Rubber-plant
Koeleria macrantha (Ledeb.)J.A. Schultes f.	June Grass
Lepidium sp.	Pepper Grass
Lesquerella arenosa S. Wats.	Bladder-pod
Liatris punctata Schreb.	Dotted Blazing-star
Linum lewisii Pursh	Wild Blue Flax
Lithospermum ruderale Lehm.	Puccoon
Lupinus sericeus Pursh	Perennial Lupine
Mirabilis hirsuta (Pursh)MacM.	Umbrellawort
Monarda fistulosa L.	Wild Bergamot
Muhlenbergia cuspidata (Torr.)Rydb.	Muhly Grass
Oenothera biennis L.	Yellow Evening Primrose
Oenothera nuttallii Sweet	White Evening Primrose
Opuntia polycantha Haw.	Prickly Pear
Orobanche fasiculata Nutt.	Clustered Broom-rape
Orthocarpos luteus Nutt.	Owl-clover
Oryzopsis hymenoides (R.&S.)Ricker	Indian Rice Grass
Oxytropis monticola A. Gray	Late Yellow Loco-weed
Oxytropis splendens Dougl.	Showy Loco-weed

APPENDIX 1. Common/botanical and botanical/common name index.

Botanical Name	Common Name
Penstemon nitidus Dougl.	Smooth Blue Beard-tongue
Penstemon procerus Dougl.	Slender Blue Beard-tongue
Petalostemon candidum (Willd.)Michx.	White Prairie Clover
Petalostemon purpureum (Vent.)Rydb.	Purple Prairie Clover
Phleum pratense L.	Timothy
Phlox hoodii Richards.	Moss Phlox
Picea pungens 'glauca'	Colorado Blue Spruce
Populus hybrid	Northwest Poplar
Potentilla concinna Richards.	Early Cinquefoil
Potentilla gracilis Dougl.	Graceful Cinquefoil
Potentilla hippiana Lehm.	Prairie Cinquefoil
Potentilla pensylvanica L.	Pensylvania Cinquefoil
Pseudostuga menziesii (Mirb.)Franco	Douglas Fir
Psoralea esculenta Pursh	Indian Bread-root
Ratibida columnifera (Nutt.)Wooten&Standl.	Prairie Cone-flower
Rhus trilobata Nutt.	Skunk-bush
Rosa arkansana Porter	Prairie Rose
Senecio canus Hook.	Prairie Groundsel
Silene noctiflora L.	Night-flowering Catchfly
Solidago canadensis L.	Canada Goldenrod
Solidago missouriensis Nutt.	Goldenrod
Solidago rigida L.	Stiff Goldenrod
Sphaeralcea coccinea (Pursh.)Rydb.	Scarlet Mallow
Stipa comata Trin.&Rupr.	Needle & Thread Grass
Stipa viridula Trin.	Green Needle Grass
Symphoricarpos occidentalis Hook.	Buckbrush
Taraxacum officinale Weber	Dandelion
Thermopsis rhombifolia (Nutt.)	Golden Bean
Townsendia exscapa (Richards.)Porter	Townsendia
Vicia americana Muhl.	Wild Vetch

APPENDIX 2. Soil analysis of samples collected from soil moisture plots (section 2.1.3).

Sample Number	Nutrients N	P	K	S	Na	Con	pH	OM (%)	Free Lime	Texture
A-4M	M/A	D	A	D	L	N	8.3-8.4	4.8-7.0	I	v. fine
B-4M	M/A	D	A	D	L	N	8.2-8.3	5.7-9.6	L/I	v. fine
C-4M	A	D	A	A	L	N	8.2-8.5	4.1-7.4	I	v. fine
D-4M	M/A	D	A	M	L	N	8.3-8.5	4.3-7.6	I/H	v. fine
E-4M	A	D	A	M	L	N	8.4	5.2-6.7	I/H	v. fine
F-4M	D/M	D	A	M	L	N	8.4-8.5	5.4-7.2	I/H	v. fine
G-4M	A	D	A	D	L	N	8.2-8.5	4.1-6.5	I	v. fine
H-4M	A	D	A	D/M	L	N	8.3-8.4	5.0-7.2	I/H	v. fine

N=nitrogen, P=phosphorus, K=potassium, S=sulphur, Na=sodium, Con=Conductivity, OM=Organic Matter;
D=deficient, M=marginal, A=adequate, L=low, N=negligible, H=high, I=medium.

APPENDIX 3. Temperature and precipitation for April-October for Pincher Creek (Environment Canada 1989).

Month	Temp.(°C) Mean Max.	Temp.(°C) Mean Min.	Total Monthly Precip. (mm)
April	10.8	–1.4	50.2
May	14.7	2.3	64.2
June	20.9	7.3	72.8
July	24.7	9.6	73.2
August	21.3	9.0	60.6
September	18.6	5.0	36.8
October	10.9	–0.3	18.2

APPENDIX 4. Relative abundance of vascular plant species in control plots of grassland restoration experiment (section 2.2.1).

Block I;Unfenced;Leeward

Species	Cover (%)* 2m	4m	8m	16m	32m
GRAMINOIDS					
Agropyron smithii	t	t	t	t	t
Koeleria macrantha	5	10	15	15	30
Stipa sp.	40	25	30	20	20
FORBS					
Achillea millefolium	–	–	–	t	t
Artemisia frigida	–	1	1	15	–
Artemisia ludoviciana	–	–	–	–	t
Aster ericoides	t	–	–	–	t
Astragalus tenellus	t	t	–	–	t
Cerastium arvense	–	–	–	1	–
Erigeron caespitosus	–	t	1	–	–
Galium boreale	–	–	–	–	t
Lesquerella arenosa	t	–	–	–	–
Linum lewisii	–	t	–	–	–
Penstemon nitidus	–	t	–	–	–
Potentilla pensylvanica	–	–	t	–	–
Sphaeralcea coccinea	–	–	t	t	–
Vicia americana	–	–	–	–	t
SHRUBS					
Rosa arkansana	–	–	t	t	t
Symphoricarpos occidentalis	t	–	–	–	t
INVADERS					
Lepidium sp.	–	t	t	–	–
Unknown1	–	2	–	–	–

Block I;Unfenced;Windward

Species	Cover (%)* 2m	4m	8m	16m
GRAMINOIDS				
Agropyrom smithii	t	t	–	t
Koeleria macrantha	7	10	20	20
Stipa sp.	30	40	25	40
FORBS				
Artemisia frigida	–	–	–	t
Artemisia ludoviciana	–	–	t	–

* t=<1%

APPENDIX 4. Relative abundance of vascular plant species in control plots of grassland restoration experiment (section 2.2.1).

Block I;Unfenced;Windward (continued)

Species	Cover (%)* 2m	4m	8m	16m
Aster ericoides	1	–	1	–
Astragalus tenellus	–	1	–	t
Gallardia aristata	–	–	t	–
Galium boreale	–	–	t	–
Hymenoxys richardsonii	t	-	t	t
Linum lewisii	–	t	t	–
Oxytropis monticola	–	–	t	–
Penstemon nitidus	–	–	t	t
Townsendia exscapa	–	t	–	–
SHRUBS				
Rosa arkansana	t	t	t	1
Symphoricarpos occidentalis	t	3	1	t
INVADERS				
Unknown crucifer	t	t	–	–

Block I;Fenced;Leeward

Species	Cover (%)* 2m	4m	8m	16m	32m
GRAMINOIDS					
Agropyrom smithii	t	t	–	t	1
Koeleria macrantha	25	25	40	25	10
Stipa sp.	20	10	10	30	30
FORBS					
Achillea millefolium	–	–	t	t	1
Artemisia frigida	2	1	1	1	–
Aster ericoides	–	t	–	–	–
Aster laevis	–	–	–	–	1
Astragalus missouriensis	–	–	–	1	–
Erigeron caespitosus	–	–	–	–	t
Galium boreale	–	–	–	t	–
Hymenoxys richardsonii	t	t	–	t	–
Oxytropis monticola	t	t	t	t	t
Penstemon nitidus	–	–	–	t	–
Potentilla concinna	t	–	t	–	–
Potentilla hippiana	–	–	–	t	–
Senecio canus	–	–	–	t	–
Sphaeralcea coccinea	–	–	–	–	t
Vicia americana	–	–	–	t	–

* t=<1%

APPENDIX 4. Relative abundance of vascular plant species in control plots of grassland restoration experiment (section 2.2.1).

Block I;Fenced;Leeward (continued)

Species	Cover (%)* 2m	4m	8m	16m	32m
SHRUBS					
Rosa arkansana	t	t	t	t	t
Symphoricarpos occidentalis	–	–	–	t	–

Block I;Fenced;Windward

Species	Cover (%)* 2m	4m	8m	16m
GRAMINOIDS				
Agropyrom smithii	–	–	1	t
Koeleria macrantha	10	25	25	20
Stipa comata	35	10	5	10
FORBS				
Achillea millefolium	–	–	t	–
Artemisia frigida	–	t	–	–
Aster ericoides	t	t	t	t
Aster laevis	–	t	3	t
Astragalus tenellus	t	–	–	–
Cirsium sp.	–	–	–	t
Erigeron caespitosus	–	t	–	–
Fragaria virginia	–	–	–	t
Galium boreale	–	t	–	t
Gutierrezia sarothrae	–	–	t	–
Hymenoxys richardsonii	–	t	1	t
Oxytropis monticola	t	t	t	1
Penstemon nitidus	–	–	t	t
Potentilla concinna	–	–	t	–
Potentilla pensylvanica	–	t	–	–
Senecio canus	–	t	t	–
SHRUBS				
Rosa arkansana	t	t	1	1

Block II;Fenced;Leeward

Species	Cover (%)* 2m	4m	8m	16m	32m
GRAMINOIDS					
Agropyrom smithii	–	t	t	–	–

* t=<1%

APPENDIX 4. Relative abundance of vascular plant species in control plots of grassland restoration experiment (section 2.2.1).

Block II;Fenced;Leeward (continued)

Species	Cover (%)* 2m	4m	8m	16m	32m
Koeleria macrantha	40	10	15	25	20
Stipa sp.	20	30	25	20	15
FORBS					
Artemisia campestris	1	–	–	8	–
Artemisia frigida	–	3	–	–	5
Artemisia ludoviciana	–	t	–	–	–
Aster ericoides	t	–	3	t	–
Astragalus tenellus	–	t	–	–	t
Cerastium arvense	–	–	–	–	5
Cirsium sp.	–	–	t	–	–
Erigeron caespitosus	–	–	–	–	t
Hymenoxys richardsonii	t	–	1	–	–
Penstemon nitidus	t	–	–	–	–
Sphaeralcea coccinea	t	–	–	–	–
SHRUBS					
Rosa arkansana	t	t	t	1	t

Block II;Fenced;Windward

Species	Cover (%)* 2m	4m	8m	16m
GRAMINOIDS				
Agropyrom smithii	–	t	–	1
Koeleria macrantha	25	10	15	15
Stipa sp.	15	20	40	25
FORBS				
Achillea millefolium	–	t	–	–
Artemisia frigida	5	1	–	–
Aster ericoides	1	1	1	t
Aster laevis	–	t	t	–
Astragalus tenellus	t	t	t	–
Gallardia aristata	–	–	–	t
Galium boreale	–	–	–	t
Helianthus nuttallii	–	t	–	–
Hymenoxys richardsonii	t	–	–	1
Linum lewisii	t	–	–	–
Oxytropis monticola	1	–	–	1
Penstemon nitidus	–	t	t	t
Potentilla gracilis	–	–	–	t

* t=<1%

APPENDIX 4. Relative abundance of vascular plant species in control plots of grassland restoration experiment (section 2.2.1).

Block II;Fenced;Windward (continued)

Species	Cover (%)* 2m	4m	8m	16m
Sphaeralcea coccinea	t	–	–	t
Townsendia exscapa	–	–	t	–
SHRUBS				
Rosa arkansana	t	1	t	–

Block II;Unfenced;Leeward

Species	Cover (%)* 2m	4m	8m	16m	32m
GRAMINOIDS					
Agropyrom smithii	2	2	2	1	1
Koeleria macrantha	15	20	35	–	15
Stipa sp.	15	15	20	20	35
FORBS					
Achillea millefolium	–	–	t	–	t
Antennaria parvifolia	–	–	–	1	–
Artemisia frigida	5	–	1	1	1
Artemisia ludoviciana	3	t	–	–	–
Aster ericoides	t	–	t	–	–
Aster laevis	–	5	t	–	–
Astragalus tenellus	t	t	t	–	–
Cerastium arvense	–	–	–	t	–
Cryptantha sp.	t	–	–	–	–
Galium boreale	–	t	–	–	–
Hymenoxys richardsonii	t	2	t	t	–
Oxytropis monticola	t	t	t	t	–
Penstemon nitidus	–	–	t	–	–
Potentilla hippiana	–	–	t	–	–
Potentilla pensylvanica	–	t	–	–	–
SHRUBS					
Rosa arkansana	t	t	2	t	3
Symphoricarpos occidentalis	1	1	–	–	–
INVADERS					
Chenopodium sp.	–	–	t	–	–

* t=<1%

APPENDIX 4. Relative abundance of vascular plant species in control plots of grassland restoration experiment (section 2.2.1).

Block II;Unfenced;Windward

Species	Cover (%)* 2m	4m	8m	16m
GRAMINOIDS				
Agropyrom smithii	2	2	–	t
Koeleria macrantha	2	20	1	5
Stipa sp.	20	30	3	40
FORBS				
Achillea millefolium	t	–	–	–
Antennaria parvifolia	t	–	–	–
Artemisia frigida	–	t	2	–
Artemisia ludoviciana	–	–	–	1
Aster ericoides	t	–	60	–
Aster laevis	–	t	–	5
Astragalus tenellus	t	t	t	t
Astragalus vexilliflexus	–	t	–	–
Fragaria virginia	–	–	–	3
Galium boreale	–	t	–	–
Hymenoxys richardsonii	–	t	t	t
Linum lewisii	t	–	–	–
Oxytropis monticola	1	t	–	–
Penstemon nitidus	–	–	t	–
Potentilla concinna	t	t	–	–
Potentilla pensylvanica	–	t	–	–
Townsendia exscapa	–	–	t	–
SHRUBS				
Rosa arkansana	2	1	–	t
Symphoricarpos occidentalis	–	1	–	t

Block III;Fenced;Leeward

Species	Cover (%)* 2m	4m	8m	16m	32m
GRAMINOIDS					
Agropyrom smithii	2	2	1	t	–
Koeleria macrantha	20	25	10	20	40
Phleum pratensis	–	–	–	t	–
Stipa comata	10	25	30	2	20
Stipa viridula	20	–	–	15	–
FORBS					
Achillea millefolium	–	–	–	–	t

* t=<1%

APPENDIX 4. Relative abundance of vascular plant species in control plots of grassland restoration experiment (section 2.2.1).

Block III;Fenced;Leeward (continued)

Species	Cover (%)* 2m	4m	8m	16m	32m
Artemisia frigida	1	t	t	–	12
Artemisia ludoviciana	–	–	–	1	–
Aster ericoides	–	t	–	–	t
Aster laevis	–	–	–	7	4
Astragalus tenellus	t	t	1	t	t
Comandra pallida	t	–	–	–	–
Gallardia aristata	–	–	–	t	–
Galium boreale	–	t	–	–	–
Hymenoxys richardsonii	–	–	–	t	t
Linum lewisii	–	–	–	t	–
Oxytropis monticola	–	–	–	t	–
Senecio canus	–	–	–	t	–
Sphaeralcea coccinea	t	–	–	–	–
SHRUBS					
Rosa arkansana	–	2	4	2	t
INVADERS					
Chenopodium sp.	–	–	t	t	–
Unknown crucifer	–	–	–	–	t

Block III;Fenced;Windward

Species	Cover (%)* 2m	4m	8m	16m
GRAMINOIDS				
Agropyrom smithii	t	–	–	t
Koeleria macrantha	35	40	25	10
Stipa sp.	30	30	30	40
FORBS				
Artemisia frigida	1	1	12	1
Artemisia ludoviciana	–	–	–	2
Aster ericoides	t	–	–	1
Astragalus tenellus	t	–	t	t
Geum triflorum	–	–	–	t
Potentilla pensylvanica	1	–	–	–
Sphaeralcea coccinea	–	–	t	–
Vicia americana	–	–	t	–
SHRUBS				
Rosa arkansana	–	t	–	t

* t=<1%

APPENDIX 4. Relative abundance of vascular plant species in control plots of grassland restoration experiment (section 2.2.1).

Block III;Unfenced;Leeward

Species	Cover (%)* 2m	4m	8m	16m	32m
GRAMINOIDS					
Koeleria macrantha	40	10	–	20	25
Bromus inermis	t	–	–	5	–
Stipa sp.	20	40	10	30	30
FORBS					
Artemisia frigida	2	–	5	–	–
Artemisia ludoviciana	–	t	–	–	–
Aster ericoides	t	–	t	1	t
Astragalus tenellus	t	t	t	–	–
Erigeron caespitosus	–	t	–	–	–
Galium boreale	–	–	t	–	–
Hymenoxys richardsonii	–	1	2	t	–
Oxytropis monticola	–	t	–	–	–
Penstemon nitidus	–	–	–	t	–
Senecio canus	–	–	t	–	–
Solidago missouriensis	–	–	–	–	1
Sphaeralcea coccinea	–	–	–	–	1
SHRUBS					
Rosa arkansana	2	1	t	–	t
Symphoricarpos occidentalis	–	2	3	2	–
INVADERS					
Descurania sp.	–	–	–	t	–

Block III;Unfenced;Windward

Species	Cover (%)* 2m	4m	8m	16m
GRAMINOIDS				
Koeleria macrantha	20	40	20	30
Stipa sp.	20	10	15	15
FORBS				
Artemisia frigida	3	3	t	2
Artemisia ludoviciana	–	1	–	–
Aster ericoides	t	t	t	1
Aster laevis	t	–	–	–
Astragalus tenellus	t	–	–	–
Hymenoxys richardsonii	1	t	–	–

* t=<1%

APPENDIX 4. Relative abundance of vascular plant species in control plots of grassland restoration experiment (section 2.2.1).

Block III;Unfenced;Windward (continued)

Species	Cover (%)* 2m	4m	8m	16m
Oxytropis monticola	–	–	t	t
Penstemon nitidus	–	–	t	t
Sphaeralcea coccinea	–	1	t	–
SHRUBS				
Rosa arkansana	t	t	–	1

Block IV;Fenced;Leeward

Species	Cover (%)* 2m	4m	8m	16m	32m
GRAMINOIDS					
Agropyrom smithii	1	–	–	–	t
Koeleria macrantha	10	20	20	5	35
Stipa comata	15	40	40	50	25
Stipa viridula	–	–	–	–	1
FORBS					
Artemisia frigida	10	2	t	t	–
Artemisia ludoviciana	t	–	–	–	10
Aster ericoides	–	–	–	t	–
Aster laevis	–	–	–	–	t
Fragaria virginia	t	–	–	–	–
Hymenoxys richardsonii	–	t	t	–	t
Linum lewisii	–	t	–	–	–
Oxytropis monticola	–	t	t	–	–
Penstemon nitidus	t	–	–	–	t
Sphaeralcea coccinea	t	t	1	–	–
SHRUBS					
Rosa arkansana	t	1	–	t	1
Symphoricarpos occidentalis	8	t	1	–	–
INVADERS					
Chenopodium sp.	–	t	–	–	–

Block IV;Fenced;Windward

Species	Cover (%)* 2m	4m	8m	16m
GRAMINOIDS				
Agropyrom smithii	–	–	–	2

* t=<1%

APPENDIX 4. Relative abundance of vascular plant species in control plots of grassland restoration experiment (section 2.2.1).

Block IV;Fenced;Windward (continued)

Species	Cover (%)* 2m	4m	8m	16m	32m
Koeleria macrantha	10	15	40	30	
Stipa sp.	30	30	10	15	
FORBS					
Achillea millefolium	–	t	2	1	
Artemisia frigida	4	4	t	–	
Aster ericoides	2	1	1	t	
Astragalus tenellus	–	t	–	t	
Hymenoxys richardsonii	t	–	1	t	
Linum lewisii	–	–	–	t	
Oxytropis monticola	t	t	1	–	
Penstemon nitidus	–	–	t	–	
Sphaeralcea coccinea	–	t	–	–	
SHRUBS					
Rosa arkansana	t	1	1	1	
Symphoricarpos occidentalis	–	–	5	1	

Block IV;Unfenced;Leeward

Species	Cover (%)* 2m	4m	8m	16m	32m
GRAMINOIDS					
Agropyrom smithii	t	–	–	2	–
Koeleria macrantha	40	20	30	30	10
Stipa sp.	12	30	20	25	25
FORBS					
Achillea millefolium	t	–	–	t	–
Artemisia frigida	2	t	8	–	t
Artemisia ludoviciana	t	–	1	–	–
Aster ericoides	–	t	–	t	t
Astragalus tenellus	t	–	t	–	t
Hymenoxys richardsonii	–	–	–	t	–
Linum lewisii	–	–	–	–	t
Oxytropis monticola	1	–	t	1	1
Penstemon nitidus	t	–	–	–	–
Sphaeralcea coccinea	–	–	t	–	–
Vicia americana	–	–	–	–	t
SHRUBS					
Rosa arkansana	t	t	t	t	5

* t=<1%

APPENDIX 4. Relative abundance of vascular plant species in control plots of grassland restoration experiment (section 2.2.1).

Block IV;Unfenced;Windward

Species	Cover (%)* 2m	4m	8m	16m
GRAMINOIDS				
Agropyrom smithii	–	–	t	–
Koeleria macrantha	10	25	45	35
Stipa sp.	30	35	15	10
FORBS				
Achillea millefolium	1	–	–	1
Artemisia frigida	t	2	5	2
Aster ericoides	t	–	–	–
Astragalus tenellus	–	–	t	–
Hymenoxys richardsonii	–	–	–	t
Oxytropis monticola	t	–	–	2
Penstemon nitidus	–	t	–	t
Phlox hoodii	–	–	–	1
Potentilla pensylvanica	t	–	–	–
Sphaeralcea coccinea	t	–	–	1
SHRUBS				
Rosa arkansana	t	–	1	t

* t=<1%

APPENDIX 5. Seedlings planted into field plot at AEC (Vegreville) in the fall of 1989.

Species	No. of Plants
Achillea millefolium	257
Arnica fulgens	103
Astragalus bisulcatus	134
Astragalus striatus	120
Heterotheca villosa	74
Gaillardia aristata	157
Geum allepicum	118
Geum triflorum	46
Haplopappus spinulosus	34
Hymenoxys richardsonii	56
Liatris punctata	44
Petalostemon candidum	28
Oenothera biennis	30
Oxytropis splendens	96
Ratibida columnifera	192
Solidago rigida	49
Oxytropis monticola	90
Erigeron glabellus	133
Senecio canus	44
Potentilla gracilis	144
Penstemon procerus	290
Hedysarum alpinum	6
Monarda fistulosa	41
Anemone multifida	51
Campanula rotundifolia	136
Grindelia squarrosa	191
Penstemon nitidus	14

APPENDIX 6. Recommended forbs for use in seed mixes for the Wildlife Habitat Mitigation Program at the Oldman River Dam Site.

Flood Zone
Geum allepicum (yellow avens)
**Glycyrrhiza lepidota* (wild licorice)
Grindelia squarrosa (gumweed)

Riparian Zone
Achillea millefolium (yarrow)
Gaillardia aristata (blanketflower; brown-eyed susans)
Geranium viscossissimum (sticky purple geranium)
Geum allepicum (yellow avens)
**Lupinus sericeus* (perennial lupine)
Monarda fistulosa (wild bergamot)
Oenothera biennis (evening primrose)
Solidago canadensis (Canada goldenrod)

Upland Zone
Achillea millefolium (yarrow)
**Astragalus bisulcatus* (two-grooved milkvetch)
**Astragalus missouriensis* (Missouri milkvetch)
Campanula rotundifolia (bluebells; harebells)
Gaillardia aristata (blanketflower; brown-eyed susans)
**Hedysarum boreale* (boreal sweetbroom)
Liatris punctata (dotted blazing-star)
Linum lewisii (perennial blue flax)
Petalostemon purpureum (purple prairie clover)
Ratibida columnifera (prairie coneflower)
Sphaeralcea coccinea (scarlett mallow)
**Thermopsis rhombifolia* (golden bean)

Gravel Pits
**Astragalus flexuosus* (slender milk vetch)
Helianthus annuus (annual sunflower)
Sphaeralcea coccinea (scarlett mallow)

* legumes.

APPENDIX 6. Recommended forbs for use in seed mixes for the Wildlife Habitat Mitigation Program at the Oldman River Dam Site.

Special Requirements

Balsamorhiza sagittata (balsam-root)

- especially on south exposures
  suitable for mid slopes, where some protection is available.

Clematis ligusticifolia (western clematis)

- for use on sites which are somewhat protected, especially around shrubs and trees, or in riparian areas along stone outcrops and cliffs.

Hedysarum boreale (boreal sweetbroom)

- on steep south exposures; especially in juniper/skunk bush areas.

Opuntia polyacantha (prickly pear)

- on steep, south exposures; especially in juniper/skunk bush areas. Probably best if propagated from cuttings (e.g. separation and rooting of individual pads.

SEED MIXES

- Forbs should be added to as many seed mixes as possible. Although every species listed need not be included in mixtures at each site it is best to include two or three forb species in each mixture.

- The amount of forb seed added to grass mixture should be between 10-20% (by weight) over and above the grass seeds.

- If seed amounts are limited it would be preferable to add sufficient amounts to specific mixtures rather than adding small amounts to all mixtures.

APPENDIX 7. Seeds collected on-site at the Oldman River Dam in 1989.

Coll. No.	Taxon	Date	Location
1	*Balsamorhiza sagittata*	14-6-89	Sec 16, Twp 7, Rg 29, W4M
2	*Astragalus flexuosus*	12-7-89	Sec 17, Twp 7, Rg 29, W4M
3	*Lupinus sericeus*	12-7-89	Sec 17, Twp 7, Rg 29, W4M
4	*Astragalus missouriensis*	12-–89	Sec 16, Twp 7, Rg 29, W4M
5	*Thermopsis rhombifolia*	13-7-89	Sec 11, Twp 7, Rg 1, W5M
6	*Agoseris glauca*	12-7-89	Sec 17, Twp 7, Rg 29, W4M
8	*Balsamorhiza sagittata*	12-7-89	Sec 17, Twp 7, Rg 29, W4M
9	*Astragalus bisulcatus*	19-7-89	Sec 33, Twp 7, Rg 1, W5M
10	*Linum lewisii*	19-7-89	Sec 33, Twp 7, Rg 1, W5M
11	*Mirabilis hirsuta*	19-7-89	Sec 33, Twp 7, Rg 1, W5M
12	*Sphaeralcea coccinea*	19-7-89	Sec 33, Twp 7, Rg 1, W5M
13	*Astragalus missouriensis*	19-7-89	Sec 33, Twp 7, Rg 1, W5M
14	*Potentilla pensylvanica*	18-7-89	Sec 16, Twp 7, Rg 29, W4M
15	*Penstemon nitidus*	8-8-89	Sec 11, Twp 7, Rg 1, W5M
16	*Petalostemon purpureum*	8-8-89	Sec 17, Twp 7, Rg 29, W4M
17	*Eriogonum flavum*	8-8-89	Sec 11, Twp 7, Rg 1, W5M
18	*Linum lewisii*	8-8-89	Sec 11, Twp 7, Rg 1, W5M
19	*Hedysarum sulphurescens*	8-8-89	Sec 11, Twp 7, Rg 1, W5M
20	*Astragalus flexuosus*	8-8-89	Sec 17, Twp 7, Rg 29, W4M
21	*Elymus piperi*	8-8-89	Sec 17, Twp 7, Rg 29, W4M
22	*Astragalus flexuosus*	17-8-89	Sec 17, Twp 7, Rg 29, W4M
23	*Oxytropis monticola*	17-8-89	Sec 11, Twp 7, Rg 1, W5M
24	*Sphaeralcea coccinea*	17-8-89	Sec 33, Twp 7, Rg 1, W5M
25	*Linum lewisii*	17-7-89	Sec 11, Twp 7, Rg 1, W5M
26	*Elymus piperi*	17-7-89	Sec 16, Twp 7, Rg 29, W4M
27	*Penstemon nitidus*	17-7-89	Sec 11, Twp 7, Rg 1, W5M
28	*Potentilla hippiana*	17-7-89	Sec 11, Twp 7, Rg 1, W5M
29	*Eriogonum flavum*	17-7-89	Sec 11, Twp 7, Rg 1, W5M
30	*Orobanche fasciculata*	17-7-89	Sec 11, Twp 7, Rg 1, W5M
31	*Astragalus bisulcatus*	16-7-89	Sec 35, Twp 7, Rg 30, W4M
32	*Galium boreale*	17-7-89	Sec 11, Twp 7, Rg 1, W5M
33	*Galium boreale*	17-7-89	Sec 16, Twp 7, Rg 29, W4M
34	*Hedysarum sulphurescens*	17-7-89	Sec 11, Twp 7, Rg 1, W5M
35	*Thermopsis rhombifolia*	17-7-89	Sec 11, Twp 7, Rg 1, W5M
36	*Oxytropis splendens*	17-7-89	Sec 11, Twp 7, Rg 1, W5M
37	*Helianthus annuus*	16-7-89	Sec 17, Twp 7, Rg 29, W4M
38	*Psoralea esculenta*	17-7-89	Sec 16, Twp 7, Rg 29, W4M
39	*Rhus trilobata*	17-7-89	Sec 16, Twp 7, Rg 29, W4M
40	*Sphaeralcea coccinea*	18-7-89	Sec 33, Twp 7, Rg 1, W5M
41	*Liatris punctata*	25-9-89	Sec 33, Twp 7, Rg 1, W5M
42	*Clematis ligusticifolia*	24-10-89	Sec 24, Twp 7, Rg 30, W4M
44	*Artemisia frigida*	13-9-89	Sec 33, Twp 7, Rg 1, W5M
45	*Stipa comata*	13-9-89	Sec 33, Twp 7, Rg 1, W5M